Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags (EFBs)

DRAFT

Version 2

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Preface

This report contains human factors considerations for the design and evaluation of "Electronic Flight Bags" (EFBs). Electronic Flight Bags (EFBs) are small, customizable information-management devices that are primarily intended for use by pilots in performing flight tasks. They aid pilots and aircraft operators in conducting flights more efficiently and safely.

An EFB typically consists of a screen and controls in a self-contained unit that is relatively small, weighing only a few pounds. EFBs could support a variety of functions, including electronic documentation, electronic checklists, flight performance calculations, and electronic charts. These EFB functions are addressed in this report.

This document is intended to support the Federal Aviation Administration (FAA) EFB Advisory Circular (AC 120-76). It contains information for FAA evaluators, system designers/manufacturers, and users about the many human factors considerations that may be associated with EFBs. Guidance is given in the form of *requirements*, *recommendations*, *suggestions*, and *issues* statements. Note, however, that this document is not regulatory. The regulatory application of this information is the responsibility of the appropriate government agencies. Where appropriate, FAA regulations and other industry documents on best design practices are referenced.

Version 1 of this document was released in September 2000 as DOT-VNTSC-FAA-00-22. Comments obtained on that document are incorporated into this document, Version 2.

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Table of Contents

Preface i
Table of Contents ii
Executive Summary vi
1 Introduction 1
1.1 Background 1
1.2 Overview 1
1.3 How to Read This Document 3
2 System Considerations 4
2.1 General 5
2.1.1 Mitigating EFB Workload in General 5
2.1.2 Compatibility and Consistency with Flight Deck Systems and Other Sources of Flight Information 7
2.1.3 Use of EFB with Other Flight Deck Systems 8
2.1.4 Using EFBs During High Workload Phases of Flight 10
2.1.5 Legibility—Lighting Issues 12
2.1.6 System Shutdown 14
2.1.7 Identifying Failure Modes 15
2.2 Physical Considerations 16
2.2.1 Stowage Area 16
2.2.2 Use of Unsecured EFBs 17
2.2.3 Design and Placement of Structural Cradle 18
2.2.4 Knee-Board EFBs 20
2.3 Training/Procedures Considerations 21
2.3.1 Part 121, Part 125, and Part 135 Operations EFB Policy 21
2.3.2 EFB Documentation for Part 121, Part 125, and Part 135 Operations 23
2.3.3 EFB Documentation for Part 91 Operators 24
2.3.4 Initial EFB Training for Part 121 and Part 135 Operators 25
2.3.5 Evaluating EFB Proficiency for Part 121 and Part 135 Operators 26
2.3.6 Fidelity of EFB Training Device 27
2.3.7 User Feedback 28
2.4 Software Considerations 29
2.4.1 User Interface—General Design 29
2.4.2 Compatibility Across Applications on the EFB and Use of Style Guides 31
2.4.3 General Use of Colors 32
2.4.4 Graphical Icons 34
2.4.5 Multi-Tasking 36
2.4.6 Responsiveness of Application 38
2.4.7 Anchor Locations 40
2.4.8 Alerts and Reminders 41

2.4.9 Display of System Status 43
2.4.10 Legibility of Text—Character Issues 44
2.4.11 Legibility of Text—Typeface Size and Width 45
2.4.12 Legibility of Text—Spacing for Readability 46
2.4.13 Non-Text Display Elements 47
2.4.14 Supplemental Audio 49
2.4.15 Ensuring Integrity of EFB Databases and Entered Data 50
2.4.16 Updating EFB Software and/or Databases 51
2.4.17 Crew Confirmation of EFB Software/Database Approval 52
2.4.18 Links to Related Material 53
2.4.19 Display Customization 55
2.5 Hardware Considerations 56
2.5.1 Pointing and Cursor Control Devices 56
2.5.2 Hardware Controls 58
2.5.3 Display 60
2.5.4 Accessibility to Hardware Components 62
2.5.5 Keyboards 63
3 Electronic Documents 64
3.1 Background 64
3.1.1 Type of Documents Addressed 64
3.1.2 Features of Electronic Documents 64
3.2 General 67
3.2.1 Consistency of Logical Structure Between Paper and Electronic Documents 67
3.2.2 Consistency of Electronic Document User Interface 68
3.2.3 Training Needs 69
3.3 Layout/Appearance 70
3.3.1 Visual Structure 70
3.3.2 Minimum Display Area 71
3.3.3 Off-Screen Text 72
3.3.4 Active Regions 73
3.3.5 Display of High Priority Information 74
3.3.6 Figures 75
3.3.7 Tables 77
3.4 Navigation and Searching 78
3.4.1 Moving to Specific Locations 78
3.4.2 Managing Multiple Open Documents 79
3.4.3 Searches 80
3.5 Options 81
3.5.1 Printing 81
3.5.2 Animation 82
3.5.3 Making Notes 83

3.5.4 Decision Aid/Automatic call-up of Data 84
4 Electronic Checklists 85
4.1 Background 85
4.2 Call-up/Access 88
4.2.1 Checklist Scope 88
4.2.2 Accessing Normal Checklists 89
4.2.3 Accessing Non-normal Checklists 90
4.2.4 Open Checklists 91
4.2.5 Multiple Open Checklists 92
4.2.6 Managing Multiple Checklists 93
4.2.7 Managing Multiple Non-Normal Conditions 94
4.2.8 Putting Away the Checklist 95
4.3 Checklist Actions 96
4.3.1 Indicating the Active Checklist Item 96
4.3.2 Moving Between Items Within a Checklist 97
4.3.3 Specifying Completion of Item 98
4.3.4 Closing a Checklist 99
4.3.5 Undoing An Item Status Change 100
4.3.6 Displaying Item Status 101
4.3.7 Returning to Deferred Items 102
4.3.8 Integrating Non-Normal Items into Subsequent Checklists 103
4.3.9 Lengthy Checklists 104
4.3.10 Confirming Completion of Checklist 105
4.4 Options 106
4.4.1 Links Between Checklist Items and Related Information 106
4.4.2 Links to Special Information for Ongoing Non-Normal Conditions 108
4.4.3 Links to Calculated Values 109
4.4.4 Task Reminders 110
4.4.5 Checklist Branching 111
4.4.6 Modifications to ECLs used for Part 121/135 Operations 112
5 Flight Performance Calculations 113
5.1.1 Aircraft Performance Documentation 113
5.1.2 Data-entry Screening and Error Messages 114
5.1.3 Support Information for Performance Data Entry 115
5.1.4 When and How to Do Performance Calculations 116
5.1.5 Default Values 117
5.1.6 Coordination Between Flight Crews and Ground Dispatch Personnel 118
6 Electronic Charts 119
6.1 Background 119
6.1.1 Review of Paper Charts 119
6.1.2 Types of Electronic Charts 120
6.1.3 Comparison of Paper and Electronic Charts 120

6.2 General 124

6.2.1 Logical and Visual Structure of Electronic and Paper Charts 124

6.2.2 Paper Corrections/Updates to Electronic Charts 126

6.2.3 Hard Copies of Electronic Charts 127

6.2.4 Scale Information 128

6.2.5 Basic Zooming and Panning 129

6.2.6 Procedures for Use of Electronic Charts in Part 121/135 Operations 131

6.2.7 Orientation of Electronic Charts 132

6.2.8 Using Charts with Other Flight Deck Displays of Spatial Information 134

6.2.9 Access to Individual Charts 136

6.2.10 Knowledge and Display of Own-Aircraft Position 138

6.2.11 Display Configuration and De -cluttering with Database Driven Charts 140

6.2.12 Color Coding of Chart Symbols 142

Appendix A: Related Literature 143

Appendix B: Acronyms 145

Executive Summary

There is currently great interest in developing electronic information management devices for use by pilots in performing flight tasks. These devices are sometimes referred to as “Electronic Flight Bags” (EFBs). EFBs typically consists of a screen and controls in a self-contained unit that is relatively small, weighing only a few pounds at most. They were originally seen as a repository for electronic documents such as checklists, operating manuals, and navigation publications. In the future, many airlines envision that EFBs may become multi-function devices supporting an array of applications beyond those of a traditional flight bag, from electronic messaging to display of live weather.

The Federal Aviation Administration (FAA) is charged with approval of EFBs for installation and operational use in aircraft. The approval process will be a multi-dimensional effort requiring an understanding of how the device functions and is used by crews, how the device interacts with other flight deck equipment, and training and operating procedures.

This document is intended to support the Federal Aviation Administration (FAA) EFB Advisory Circular (AC 120-76). It contains information for FAA evaluators, system designers/manufacturers, and users about the many human factors considerations that may be associated with EFBs. Guidance is given in the form of *requirements*, *recommendations*, *suggestions*, and *issues* statements. Note, however, that this document is not regulatory. The regulatory application of this information is the responsibility of the appropriate government agencies. Where appropriate, FAA regulations and other industry documents on best design practices are referenced.

Version 2 of this human factors document covers system considerations and four EFB functions in detail. The functions discussed in Version 2 are electronic documents, electronic checklists, flight performance calculations, and electronic charts. Human factors guidance for more complex functions, such as surface moving map and weather applications, may be found from the work of the appropriate standards committees sponsored by RTCA and SAE G-10.

1 Introduction

This document is intended to support the Federal Aviation Administration (FAA) EFB Advisory Circular (AC 120-76). It contains information for FAA evaluators, system designers/manufacturers, and users about the many human factors considerations that may be associated with EFBs. The considerations apply generally to all operations (Part 91, Part 121, Part 125, and Part 135), except where explicitly noted. This document is not regulatory. The regulatory application of this information is the responsibility of the appropriate government agencies. Where appropriate, FAA regulations and other industry documents on best design practices are referenced.

Chapter 1 contains background information on the Advisory Circular from the Federal Aviation Administration and an overview of the structure of this document. There are separate chapters for system considerations, which are independent of the function(s) supported by the EFB, and four specific EFB functions. The functions addressed in this document are electronic documents, electronic checklists, flight performance calculations, and electronic charts. Human factors guidance for more complex functions, such as surface moving map and weather applications, may be found from the work of the appropriate standards committees sponsored by RTCA and SAE G-10.

1.1 Background

The FAA's AC120-76 defines three classes of EFB for the purpose of field approvals. Class 1 EFBs are self-contained devices that do not interface electronically or mechanically with the aircraft; these are considered to be portable electronic devices subject only to Flight Standards approval. Class 2 EFBs are connected to the aircraft in some way (e.g. a mechanical connection via a structural cradle, an electrical connection for power, or even a data link connection for acquiring data). Class 2 EFBs are subject to approval by both Flight Standards and, to a lesser extent, Aircraft Certification. Class 3 EFBs must undergo a full review by Aircraft Certification.

From a human factors perspective, these distinctions are important in that they denote *two* major levels of capability; devices that read data from aircraft systems (Class 2 or Class 3 EFBs) support more integrated functionality than those that do not. These EFBs could sense the status of aircraft systems and automatically bring up information, if necessary, to address an abnormal situation. Throughout this document, we distinguish issues relevant only to EFBs that are integrated with other aircraft systems from issues relevant to EFBs that do not communicate with aircraft subsystems.

1.2 Overview

This document contains guidelines on specific topics for the FAA and avionics manufacturers in Sections 2 through 6. Section 2 contains system considerations while Sections 3, 4, 5, and 6 cover electronic documents, electronic checklists, flight performance calculations, and electronic charts in order. Appendix A contains a list of references, and Appendix B contains a list of acronyms.

Section 2 (System Considerations) contains several individual "considerations," the format of which is described below. Section 3 (Electronic Documents) begins with background about the different types of document capabilities. Readers who are familiar with these concepts and terms could skip this section and move directly to the considerations that follow. Section 4 (Electronic Checklists) also begins with background material on electronic checklists, and a description of terms. Again, readers who are familiar with these terms can move directly to the considerations that follow. Section 5 (Flight Performance Calculations) contains only considerations. Section 6 (Electronic Charts) contains an introduction followed by considerations.

The title of each consideration describes the general subject. It is followed by one, two, or three icons (an airplane, faces, or a computer). If there is an airplane icon, then there are guidance statements in the consideration related to the *installation* of the EFB in an aircraft. The icon with faces indicates that there are guidance statements related to the *training/procedures* for the use of the EFB.

The computer icon indicates that there are guidance statements related to the hardware/software aspects of the EFB *equipment*. The same icons are shown in the Table of Contents to help the reader browse the document.

Each consideration may have one *or more* boxed summary statements at the top of the page. Each of the statements is preceded by a descriptive label, such as "Equipment Requirement", or "Installation Recommendation." The purpose of these labels is to identify (a) what aspect of FAA approval the statement concerns, and (b) the type of information in the statement.

The three descriptive labels used are: "Equipment," "Installation," or "Training/Procedures." These categories are separated out to assist readers who are coming from a specific one of these perspectives to browse the document. Equipment guidelines are “box level” design items which can typically be assessed in a bench test; i.e., these items are testable outside the context of the aircraft. Some equipment issues are more focused on software issues, while others are more focused on hardware issues. However, a particular EFB may have implemented a particular type of function either through hardware or software, or through some combination. Therefore, it is not possible to determine in advance whether the issue is to be addressed at the hardware or software level. The applicability of each equipment issue to a given product must be determined at the time of the review.

Installation issues are those that must be tested within the context of the aircraft flight deck. Because EFBs may be portable, some issues may be both "Equipment" and "Installation" issues. Training/Procedures issues are, of course, related to training and procedures rather than the design or installation of the equipment itself.

The information within a boxed summary statement in a consideration can be one of four types: requirements, recommendations, suggestions, and issues. Each type of information is designated by a different style of text, as shown in Table 1.2.1. As indicated by the labels, requirements are mandatory and recommendations denote highly preferred methods or mechanisms. In general, compliance with recommendations is highly desirable whereas compliance with suggestions should be considered, but may not be suitable for every situation. Note, however, that this document does not focus on best practices, so there are relatively few Suggestions. Where possible, we refer to additional documents that may contain best practices for design. "Issues" differ from the other types in that they are descriptive, rather than prescriptive statements. That is, Issues statements point out design tradeoffs and options that should be considered during design and evaluation without specifying a “correct” or “best” solution.

Each consideration begins on a new page. To browse the document, read just the summary statements in each of the boxes. For more information about that issue, read the rest of the page, which has more detailed information about the consideration in one or more of the sections below the summary statements. These sections are labeled: Problem Statement, Example(s), and Evaluation Questions. The Problem Statement describes the problem that the summary statements apply to, including the potential impact if the problem is not addressed. The Example(s) section contains examples of the potential problem, and possible solutions. The Evaluation Questions section lists open ended questions that an FAA inspector should consider when determining whether the problem has been adequately addressed. The Evaluation Questions do not provide detailed guidance on performance assessment, but they do point out areas for evaluation.

Table 1-1 Elements of each Consideration

Requirements are shaded and boxed with a bold outline. These are the items the authors feel are mandatory. However, it should be noted that this is not a regulatory document and that any application of these requirements is the responsibility of the appropriate regulatory agency (such as the FAA in the United States).
Recommendations are boxed within a bold outline. These are highly preferred methods or mechanisms.
Suggestions are boxed within a thin outline. These are options that have proven successful in the industry, but may not be appropriate in all circumstances.

Issues are boxed within a double line. These are descriptive (not prescriptive) statements that point out design tradeoffs and other related factors.

1.3 How to Read This Document

This document is designed to be read by both FAA personnel (from various offices) and avionics manufacturers and customers. From the manufacturer's perspective, each consideration should be read completely, starting with the summary statements (requirements, recommendations, etc.). The rest of the material (Problem Statement, Examples and Evaluation Questions) should be helpful in illustrating the spirit of the guidelines.

Because the FAA readers are themselves a diverse audience, sections are labeled for ease of browsing. Aircraft Certification personnel should focus more on Equipment and Installation Requirements. Flight Standards personnel should find topics of relevance throughout, with particular emphasis on Equipment and Training/Procedures requirements. Principal Operations Inspectors (POIs) and Principal Avionics Inspectors (PAIs) may find the Evaluation Questions particularly important.

2 System Considerations

System considerations apply to any EFB, regardless of the function, or functions, performed by that EFB. These considerations are divided into five categories: General, Physical, Training/Procedures, Software, and Hardware.

2.1 General

2.1.1 Mitigating EFB Workload in General

Training/Procedures and Equipment Recommendation(s)

> Operational procedures and EFB software/hardware should be designed to mitigate any additional workload and head-down time of using EFB in all phases of flight (see FAR 25.1523 on Crew Workload). The risk of distraction from an EFB should also be minimized.

Training/Procedures Issue(s)

> It is often difficult to measure workload differences between tasks, particularly because workload is often shifted around. Designers and evaluators should be aware of workload tradeoffs. They should always be asking where the workload is going, and not just whether the workload is decreased or increased.

Problem Statement

Any new technology used by the flight crew has the potential to decrease workload associated with some tasks, and to increase workload associated with other tasks. The goal is to decrease overall crew workload, or at least to maintain the workload at current levels.

To ensure that the EFB does not increase overall crew workload, operational procedures should be designed to mitigate any additional workload and head-down time of using the EFB. In addition, EFB software and hardware should be designed to mitigate these same problems. Increased workload could result from inefficient design of the software or hardware, or even some limitations in the flexibility of using EFBs in relation to paper documents.

Example(s)

An EFB may provide flight crews with a new capability, such as that of completing weight and balance calculations. This new responsibility may be in addition to all the other tasks that the flight crew is used to performing, so in a sense it is an increase in the flight crew's workload. Procedures should ensure that the workload associated with this type of new task is acceptable. For example, the crews may be allowed to update weight and balance computations only while at the gate, rather than during taxi, or they may use these functions only to *review* or *modify* calculations while taxiing, rather than to create the full flight plan from scratch.

Paper documents require a certain amount of attention and workload to access; the pilot has to determine which book or set of papers is the appropriate one for the information he or she is seeking, get that book or set of papers out, and find the information. The EFB will also require attention and workload; the pilot will have to access the EFB and navigate to the desired information. The workload required to access any given piece of information with the EFB should be less than or equal to the workload required to do so with paper documents. Note that there may be differences in both mental and physical workload (reaching, manipulating, and viewing) and mental workload (the thought required to identify and find the desired information).

Instead of supporting new tasks, an EFB may allow flight crews to perform existing tasks more efficiently, such as looking up reference information from a flight manual. In this case, the design of the software search procedure can affect the risk of getting lost in the process of searching for information, or the risk of becoming distracted by a search that results in too many choices. An appropriate design of the search procedure should mitigate these risks.

Hardware controls (e.g., thumbwheels, knobs, toggle switches) should be selected appropriately for the task. For example, it is more likely that a thumbwheel will be inadvertently adjusted than a rotary knob with detents, so thumbwheels should not be used when accidental manipulation is to be strongly discouraged.

Paper charts are lightweight and small enough that pilots can place them in a convenient and comfortable location for use during approach, such as on the control column, or even on kneeboard. An EFB, however, may be more difficult to position than a paper chart, so it is less flexible than paper in this sense. The reduced flexibility of positioning an EFB may affect the pilot's task in terms of changes in head down time and workload.

Evaluation Question(s)

- What are the operational procedures in place for mitigating any additional workload, head-down time, and distraction that are potentially associated with EFB functions?
- How does the software and/or hardware design mitigate the risk of increased workload, head-down time, and distraction?

2.1.2 Compatibility and Consistency with Flight Deck Systems and Other Sources of Flight Information

Installation and Equipment Recommendation(s)

> The user interface of the EFB should be compatible with the crew interface and flight deck design philosophy of the particular aircraft in which it will be used.
>
> The EFB system should be designed to minimize flight crew error and maximize the identification and resolution of errors. For example, terms for specific types of data or the format in which latitude/longitude is entered should be the same across systems. Data entry methods, color coding philosophies, and symbology should be as *consistent* as possible between the EFB and other flight deck systems and paper documentation (such as dispatch papers, weather reports, etc.).

Problem Statement

Today's complex, integrated flight decks are designed with an overall flight deck design philosophy in mind. The design philosophy guides system development in important and sometimes subtle ways to enhance overall simplicity and safety. While pilots may not be able to state what the flight deck design is verbally, they do develop implicit expectations of how the aircraft will operate based on their experience with that flight deck.

When a new system, such as the EFB, is introduced into an existing flight deck, it is important that the pilot's expectations of how the aircraft operates are not violated by the EFB. If the EFB is incompatible with the overall flight deck design, pilots will have trouble learning to use it, and they will be more likely to make errors.

This is also true of the information generated by the operator and its service providers. Airlines maintain documentation and information services that rely on particular formats for information, and information provided by the EFB should be consistent with them.

Example(s)

One design philosophy, implemented by the Boeing Company, is that the flight deck should normally be "quiet and dark." By this, designers mean that the flight deck should (a) be as dark as possible during night-time operations so that the pilots' eyes become dark adapted, easing the transition between outside and inside viewing, and (b) in general, there should be few or no lit status indicators or audible alerts during normal conditions. To be consistent with the quiet/dark philosophy, EFBs should also be designed with dark displays (i.e., black backgrounds with lighted text), and they should have few or no visual status indicators or associated audible alerts in normal operations.

Examples of other sources of flight information that the EFB should be consistent with include dispatch information, maintenance documentation, and weather forecasts. These documents use units of measurement, abbreviations, and symbols that should be used consistently on the EFB.

Evaluation Question(s)

- Is the user interface of the EFB compatible with the philosophy of the flight deck?
- Does the EFB minimize the potential for crew error by using terms, color codes and symbols consistent with flight deck systems and other sources of flight information?

2.1.3 Use of EFB with Other Flight Deck Systems

Training/Procedures Requirement(s)

Procedures must be designed to ensure that the crew knows what flight deck automation system (e.g., EICAS, FMS, or EFB) to use for a given purpose, especially when information/data is provided by both aircraft and EFB systems.

Procedures should also be designed to define actions to be taken when information provided by an EFB does not agree with that from other flight deck sources, or when one EFB disagrees with another.

If an EFB generates information that existing flight deck automation also generates, procedures must be developed to identify which information source will be primary, which source will be used as a backup, and under what conditions to use the backup source.

Problem Statement

Whether or not there is any communication between aircraft systems and the EFB, from the perspective of a crew member, the EFB is just another tool for him/her to use. If there are inconsistencies or redundancies in the information provided by the different automation systems ("tools"), there will be confusion and increased potential for errors.

Therefore, regardless of whether there is a data connection between the flight deck systems and the EFB, information consistency/redundancy must be considered when integrating an EFB into an aircraft with other advanced systems, such as a Flight Management System (FMS) or Engine Indication and Crew Alerting System (EICAS).

Example(s)

EFBs may support electronic checklists. On some Airbus aircraft, electronic checklists for emergencies are built into the Electronic Centralised Aircraft Monitor (ECAM), and paper checklists are provided as well. Procedures must be established to ensure that crews know which of these checklists should be used, particularly in an emergency.

In a hypothetical example, it is possible that the EFB and FMC could both compute performance data separately. Crews must know which performance data are to be used for the flight, and they must ensure, if appropriate, that these are the data in use by automation on the aircraft (e.g., the FMC and/or auto-pilot). Performance data disagreement between an EFB and an FMS may cause the pilot to set speed bugs to incorrect values for autothrottle-controlled takeoffs and may result in sub-optimal cruise speeds or surprising FMS behaviors, such as unexpected predicted speeds, estimated times enroute, and top of descent points.

Electronic charts used for takeoff or landing may either replicate paper charts with north up, or give pilots the option of north up or track up. North up only runs the risk of causing errors because pilots must perform mental spatial transformations in order to follow the path. However, pilots are used to doing this. If a track up option is provided, it may be easier to compare the chart display with the navigation display view. The major potential for error, though, may lie in the possibility that the chart will be in the track-up orientation and the navigation display in north-up orientation, since this is likely to be the least-used combination and it may occur more by error than by intent. If so, it is likely that pilots will misread the chart or the moving map because it is in a different orientation than they expected. One way of preventing this kind of error is to only allow the EFB chart to show heading up when it is connected to the avionics and the navigation display is in the same mode. When the EFB is not so connected and the track-up orientation is not available, there must be clear feedback to the pilot to that effect if he or she tries to select track-up orientation.

Evaluation Questions

- What are the procedures for establishing which source of information is primary?
- What procedures does the crew follow if there is a disagreement between the EFB and other flight deck systems, or between multiple EFBs?

- Under what conditions will the backup source of information be used?

2.1.4 Using EFBs During High Workload Phases of Flight

Training/Procedures, Equipment, and Installation Recommendation(s)

If the EFB is used in high workload phases of flight, such as take-off and landing, its use should be evaluated through simulations and actual flight testing under those conditions. Workload arising from the procedures for using the EFB, its hardware and/or software, and even the installation of the device should be considered during the evaluation.

An EFB that is designed for use during high workload phases of flight should be used while in a structural cradle to minimize the workload of positioning the unit for use. Unsecured EFBs are not recommended for use in high workload phases of flight.

Training/Procedures, Equipment, and Installation Issue(s)

EFBs could also distract crews from higher priority tasks. Procedures, policies, and perhaps even built-in limits on the use of the EFB may be useful in addressing this problem, particularly for EFBs that have knowledge of aircraft system status (e.g., lock out access to non-flight applications in flight).

Training/Procedures Recommendation(s)

Complex, multi-step data entry tasks should be avoided during takeoff, landing, and other high workload phases of flight.

Problem Statement

Using an EFB requires effort. There may be effort involved in locating and orienting the display for use and there is effort in looking at the display, processing the information, and making any necessary entries. Data entry can produce particularly long head-down times and high workload. Visual scanning of the EFB (without data entry) does not require as much effort, but it is still an additional task for the pilot.

The additional workload required to use an EFB may distract the pilot from higher priority time-critical tasks, which is particularly detrimental during high workload phases of flight. Ultimately, workload issues during high workload phases of flight could potentially affect the certification basis of FAR 25.1523 (Minimum Crew Size).

When evaluating the workload incurred by use of an EFB, the evaluator should consider factors such as the time it takes to complete the task using the EFB, as compared with doing the task without the EFB. The location and accessibility of the EFB display and controls, the amount of automation, and the usability of the EFB software will all affect the time it takes to complete a task using the EFB. The evaluator should also consider whether users would be more likely to make errors during high workload conditions, whether it is easy to recover from errors, and whether users are likely to become distracted from other flight deck tasks while resolving EFB problems.

Example(s)

During high workload situations, such as takeoff and landing, entering data on the EFB may distract the crew from essential functions, such as visual scanning for air traffic out the window, or scanning of aircraft instruments. Data entry tasks should be avoided during these phases of flight. If data entry is required, it should be limited to a single key press. For example, to indicate that the “climb out” checklist has been completed, the pilot may enter a yes/no response to an EFB inquiry.

If, however, the EFB is used as a display of real-time information useful during landing (e.g., if the EFB displays nearby traffic during landing), and only requires occasional scanning that the pilot can incorporate into his/her task schedule, the additional workload may be acceptable.

An EFB that has more built-in automation may also be more acceptable for use under high workload conditions. For example, if some items in an emergency checklist are completed through closed-loop sensors, the pilot's workload may not be impacted negatively by using the EFB as compared with the paper checklist.

Some EFBs that have knowledge of aircraft system status may have built-in limits, such as the inability to exercise certain functions below 10000 ft altitude.

Evaluation Question(s)

- What training and/or procedures are in place to mitigate any additional workload of using the EFB under high workload conditions?
- Are complex, multi-step data entry tasks avoided during takeoff, landing, and other high workload phases of flight?
- Are there built-in limits on use of the EFB?
- If the EFB is designed for use during high workload phases of flight, is it secured within aircraft?

2.1.5 Legibility—Lighting Issues

Installation Requirement(s)

> The EFB display must be legible to the typical user under the variety of lighting conditions expected in a flight deck, including use in direct sunlight.

Installation and Equipment Requirement(s)

> Users must be able to adjust the screen brightness of an EFB independently of the brightness of other displays in the flight deck.

Equipment Requirement(s)

> If automatic brightness adjustment is incorporated, it must operate independently for each EFB in the flight deck.
>
> If the EFB will be used away from the flight deck (e.g., outdoors, or in a home/office setting), text on the EFB must be legible to the typical user under the expected lighting conditions for use.

Equipment Recommendation(s)

> Screen brightness should be adjustable in fine increments or a continuous rather than discrete manner.
>
> Buttons and labels should be adequately illuminated for night use.

Equipment Issue(s)

> There may be special considerations for EFBs to be used with other devices, such as head-up displays or night vision goggles, where additional lighting issues need to be considered.
>
> The range of brightness that should be supported by an EFB has not been settled. In general, a broad range of brightness is highly desirable in order to maximize display usability in both nighttime and bright daylight operations.

Problem Statement

Ambient lighting conditions may vary from very dark during a night flight to direct sunlight on the display. The EFB display must be usable under all of these lighting conditions. This will require at least some ability to adjust the screen brightness. In addition to screen brightness, the size of the text, font style, contrast, glare/reflections, display quality, colors, viewing distance, and off-angle viewing will all affect text legibility. If the EFB is portable, legibility should be checked both inside and outside the flight deck.

Screens or text that are not legible will cause pilot distraction at the least (as the pilot attempts to position the display for better legibility) and potentially more harmful consequences if important information is misread, or not read at all.

Example(s)

Different font styles may be used at the same time on an EFB. The different fonts may indicate something about that information. For example, one font style may denote the active checklist item (e.g., white, large font) and another font style could represent a completed item (e.g., green, small font). Because the font styles can encode important information, all of the font styles on the screen must be legible and easily discriminated from one another without any screen adjustments.

Evaluation Question(s)

- Can the EFB screen be read under a variety of typical flight-deck lighting conditions? Can the EFB screen be read outside the flight deck?
- Can the user adjust the screen brightness and contrast (if applicable)?
- Are buttons and labels adequately illuminated for night use?

2.1.6 System Shutdown

Installation, Equipment, and Training/Procedures Requirement(s)

> Shutdown procedures for EFBs must be designed such that:
>
> a) flight crews can incorporate it into their normal aircraft shutdown procedures without undue difficulty, and
>
> b) the EFB operating system remains stable after multiple start-ups and shutdowns in the aircraft

Problem Statement

Crews routinely shutdown airplane systems by turning off the power supply; they do not expect to “wait” for systems to complete their shutdown routines before cutting the power. However, some EFB operating systems need to perform shutdown routines before the power is cut in order to work properly the next time they are started. If the power is cut abruptly, the EFB operating system may be corrupted and fail to function.

Example(s)

Standard desktop operating systems such as Windows™ perform shutdown procedures that take several seconds, if not minutes to complete. For continued stable use in the flight deck, the shutdown procedures for a Windows™-based EFB must be initiated well in advance of shutting down power to the aircraft.

Evaluation Questions

- What are the procedures for shutting down the EFB?
- Are the shutdown procedures designed for long-term stability of the EFB and ease of crew operation?
- What happens if the crew cuts power to the EFB instead of shutting it down properly? Does the EFB function correctly when rebooted?
- If the EFB hangs and fails to respond to crew input, or displays error or fault messages, are the means of recovery easy to remember and apply? Does the crew have to remember any arbitrary procedures or refer to documentation in order to restart the EFB?

2.1.7 Identifying Failure Modes

Equipment and Training/Procedures Recommendation

The effects of undetected errors in all EFB applications should be evaluated for each application. The assessment should address the adequacy of the human/machine interface, accessibility of controls, ability to view controls, annunciations, displays and printers, and the effect on flight crew workload and head-down time. The assessment should also consider the effects of flight crew (procedural) errors determined by comments from the professional pilot community. The EFB system should be capable of alerting the flight crew of probable EFB application/system failures.

Problem Statement

There is a need to identify and classify failure conditions for each EFB application in order to evaluate the effects of undetected errors in all EFB applications.

Failure modes and effects analysis. Identify failure modes

If there are errors in how the applications are specified, or device does not do what it is supposed to do,

Assume errors, focus on consequences. Failures are limited to access of the information if pre-composed. If interactive information, opens up a class of failures.

Need input from FAA here.

Example(s)

TBD. Procedures to follow when one unit fails, where multiple units are carried on board the aircraft.

One possible system error that may occur is that the navigation data base used by the flight guidance system may differ from the version of the charts in the EFB. This may cause unexpected behavior, as the aircraft follows a different trajectory along the approach path under autoflight than the one depicted in the chart.

Another possible error has to do with display orientation. If the chart display is north up and the navigation display is track up, a pilot asked to change to a parallel runway late in the approach to a south facing runway in IMC may turn the wrong way to intercept the new runway.

Evaluation Question(s)

TBD.

2.2 Physical Considerations

2.2.1 Stowage Area

Installation Requirement(s)

> A stowage area with a securing mechanism for the EFB is required for storage of EFBs when they are not in use. The stowage area must be in compliance with FAR 25.787 and FAR 25.789.
>
> Note: If the EFB is designed to be held in a structural cradle, the cradle may satisfy the requirement for a stowage area.
>
> Note: For EFBs that are used in light aircraft operating under Part 91, this requirement may be downgraded to a recommendation.

Installation Recommendation(s)

> The stowage area and securing mechanism should not be mounted such that they obstruct visual or physical access to controls and/or displays, flight crew ingress or egress, or external vision.
>
> The EFB should be stowed such that is easily accessible by a wide population of users. It should not be in a space that is awkward to reach, or of such a weight and size that it is difficult to manipulate in the given space.
>
> The stowage location for the EFB should not result in unacceptable crew workload incurred by the need to locate, retrieve, and orient the display.

Problem Statement

Flight deck real-estate (not just display space) is extremely limited. Every device routinely used in the flight deck must have a designated place, when both in and out of use. Stowage areas must be accessible to crew members without interfering with normal or emergency flight tasks.

The stowage area provides a means of securing EFBs that are unsecured during normal use, including both self-contained devices and those that are tethered to the aircraft.

Example(s)

EFB units may move unexpectedly during significant accelerations. For example, a unit left on an unused seat may fall off the seat during turbulence. The next time the pilot attempts to use the device, finding the unit will cause pilot distraction at the least.

During takeoff and landing, the EFB may need to be stowed in order to prevent injuries to the crew in case of sudden aircraft accelerations, similar to the requirement for stowing tray tables for passengers.

Evaluation Questions

- Is there a stowage area for the EFB? When the EFB is not stowed, is the securing mechanism in the stowage area unobtrusive?
- When the device is stowed, does the combination of it and the securing mechanism intrude into any other flight deck spaces, causing either visual or physical obstruction of important flight controls/displays?
- Does movement of the EFB to and from a stowage area require substantial effort, or substantially limit access to flight displays and controls? Is the securing mechanism simple to operate for a wide population of users?

2.2.2 Use of Unsecured EFBs

Requirement

> EFBs must be used in a manner that prevents the device from jamming flight controls, damaging flight deck equipment, or injuring flight crewmembers should the device move about as a result of turbulence, maneuvering, or other action.
>
> There should be a means of securing the EFB, both while in and out of use to meet this requirement.

Training/Procedures Recommendation(s)

> Crews should routinely store EFBs that are not actively in use while in flight.
>
> While in use, EFBs that are not held in a structural cradle should not be routinely placed such that they obstruct access to flight controls/displays.

Equipment and Training/Procedures Recommendation(s)

> EFB systems that are not secured in a structural cradle while in use should be designed and used in a manner that prevents the device from jamming flight controls, damaging flight deck equipment, or injuring flight crewmembers should the device move about as a result of turbulence, maneuvering, or other action.

Problem Statement

One advantage of having an unsecured unit is that the whole display can be physically manipulated. This might be especially useful for a simple electronic chart application that shows only north-up static charts. Instead of developing a complex track- or heading-up display option, the entire display could be rotated if desired. Similarly, another advantage of an unsecured display is that it could be positioned close to other flight deck displays with which the pilot may want to compare data.

However, unsecured EFBs that do not have designated storage and use locations can be a hazard for a number of reasons:

1) They may obstruct access to other displays/controls.

2) In the case of strong accelerations, such as those in takeoff, landing, and turbulence, an unsecured EFB could fall and jam rudder pedals or limit aft yoke travel. Unsecured units could also cause physical injury to the crew under these conditions.

3) There could be confusion when crews attempt to locate, orient, and use portable, unsecured EFBs. This problem will be especially pronounced if the EFB is physically large enough, relative to the size of the flight deck, so as to be difficult to move about quickly and easily.

Example(s)

An EFB might be placed on the pilot's lap during takeoff (perhaps using a securing strap). If so, the pilot must insure that he/she has full control authority, i.e., that the yoke can be pulled back completely and the control wheel rotated to full travel without the EFB getting in the way.

Evaluation Question(s)

- Does the pilot have adequate access to flight controls and displays when the unsecured EFB is in use?
- What are the procedures and/or training for where an unsecured EFB should be placed when in use, and when out of use?

2.2.3 Design and Placement of Structural Cradle

Installation and Equipment Requirement(s)

Note: A structural cradle is a piece of hardware that is (a) physically attached to the aircraft and (b) designed to hold the EFB while it is in use.

If a cradle is added to the airplane, it must meet FAR 25.561 or 25.562 regarding safety during dynamic or static emergency landing conditions.

When the EFB is in use and is intended to be viewed or controlled, it should be within 90 degrees on either side of each pilot's line of sight.

Note: A 90° viewing angle may be unacceptable for certain EFB applications if aspects of the display quality are degraded at large viewing angles (e.g., the colors wash out or the color contrast is insufficient at the installation viewing angle). Each EFB should be evaluated with regard to viewing angle requirements.

Installation Recommendation(s)

If an EFB is being used to display high priority flight information such as for navigation, terrain and obstacle warnings that require immediate action, takeoff and landing V speeds, or for functions other than situation awareness, then such information should be in the pilot's primary field of view, well inside the 90° viewing angle requirement.

The structural cradle should not be mounted such that it obstructs visual or physical access to controls and/or displays intended for use by the flight crew, flight crew ingress or egress, or external vision. (See FAR 25.1321.)

The cradle should allow easy access to all EFB controls and a clear view of the EFB display.

The structure and associated mechanism should not impede the flight crew in the performance of any task (normal, abnormal, or emergency) associated with operating any aircraft system.

The cradle should be mounted such that the pilot does not have to turn him- or herself significantly to use the device, particularly during critical phases of flight. The cradle should also be easily accessible by a wide population of users. It should not be placed in a space where it is awkward to reach or manipulate the EFB.

The cradle should allow for some adjustment of the EFB orientation to allow pilots to (a) customize the viewing angle to some extent and (b) alter the pattern of ambient light that falls on the display to reduce significant glare and reflections, which could impact its readability.

Cradle structures should be able to lock in position easily. Selection of locking positions should be fine enough to accommodate a range of crewmember preferences. In addition, the range of available selections should accommodate the expected range of users' physical abilities (i.e., anthropometrical constraints).

The cradle should allow the user to lock the EFB in a position that is out of the way of flight crew operations when not in use. The cradle should be mounted so that the EFB is easily accessible when stowed.

If the EFB requires cabling to mate with aircraft systems or other EFBs, and if the cable is not run inside the cradle structure, the cable should not hang loosely in a way that compromises task performance and safety. Flight crewmembers should be able to easily secure the cables out of the way during aircraft operations.

The installation of the EFB should minimize any additional workload incurred by the need to locate and orient the display, particularly if used during critical phases of flight.

Training/Procedures Requirements(s)

> Crews must know how and when to adjust the cradle position, their own seating position, or the placement of the EFB unit such that they have easy access to, and a clear view of, the EFB.
>
> Procedures must ensure that pilots have good access to all flight controls and displays, even those that are partially obstructed by the EFB and its cradle when necessary.

Problem Statement

Devices that are added into older flight decks could obstruct access to or use of other equipment. A structural cradle can help assure that the device is positioned appropriately for use.

The pilot must not be required be use an EFB that is located behind him/her because that position is more likely to distract him/her from important tasks, such as scanning out the window for traffic.

Example(s)

The structural cradle could be on the yoke of the aircraft. In this case, the pilot must adjust his/her seat position in order to have a clear view of the EFB and other flight deck displays.

Pilots who are unfamiliar with an approach into a given airport might prefer to have the EFB electronic chart on the control column so he or she can learn the procedure while following flight director guidance. If the EFB cannot be mounted in front of the pilot as a paper chart can, it may make following a procedure more difficult. The pilot would have to look to the side instead of to the front. This could result in more head down time and higher workload, including more mental workload to associate the chart depiction with the pilot's current position in the procedure.

The structural cradle could be positioned to the side of the pilot, just outside the existing flight deck panel. Again, the pilot may have to adjust his/her seat to be at the reference eye position.

Evaluation Question(s)

- Is the cradle positioned in front of the pilot? Does it obstruct visual or physical access to flight controls and/or displays? Which controls/displays are affected, and how important are they during the different phases of flight in which the EFB will be used?
- Do crews know how to adjust and lock the EFB or their own orientation for optimal viewing or for stowage? Is there adequate room to manipulate the device controls and view its display?
- Is the EFB installed for easy access during critical flight phases?

2.2.4 Knee-Board EFBs

Installation and Training/Procedures Requirement(s)

> Note: Knee-board EFBs are those which are secured to the pilot's leg. They are not cradle-mounted or hand-held.
>
> Knee-board EFBs must allow the pilot to exercise full control authority.
>
> Pilots must follow a procedure to check that the EFB is properly positioned prior to each flight.

Installation Recommendation(s)

> The securing mechanism holding the knee-board EFB should be designed for both pilot comfort and convenience in attaching/removing.

Installation Issue(s)

> Head-down time associated with use of a knee-board EFB should be carefully evaluated. Also, spatial disorientation may be more likely with such a design, especially if the pilot has to look down during while accelerating (e.g., while turning).

Equipment Issue(s)

> Knee-board EFBs may be in physical contact with the pilot throughout the flight. The heat generated by these devices should be evaluated to ensure that it is acceptable. Also, the weight of the unit on the pilot's leg may be fatiguing after some time.

Problem Statement

Pilots often strap clipboards with paper charts and flight information to their knees. There may be some EFB designs based on this familiar configuration. When pilots use clipboards for paper information, they are responsible for ensuring that the clipboard is properly positioned and does not limit their control authority prior to every flight. The same must be true for any electronic device strapped to the pilot’s knee.

Electronic devices differ from clipboards in that they typically weigh more, and they generate heat. It is important that the effects of these factors are mitigated for the comfort of the crew. Another negative aspect of using a knee-board EFB is that looking down at one’s knees during accelerations can induce spatial disorientation, so this possibility should also be evaluated.

Example(s)

Use of knee-boards is particularly common in single-pilot operations (e.g., small general aviation, or military operations). The kneeboard is typically the size of an approach chart and weighs less than 1 lb (approximately 450 g). It holds a few approach charts and notes on weather conditions, air traffic clearances, etc. An electronic version of such a device may need to be a smaller physical size in order to meet the weight constraint.

Knee-boards are often used to take hand-written notes in general aviation operations. An electronic device that replicates this functionality may need to support hand-writing recognition, and have a suitable storage place for a stylus.

Evaluation Questions

- Can the knee-board EFB be positioned such that the pilot has full control authority?
- Is the knee-board EFB comfortable for the pilot to wear?

2.3 Training/Procedures Considerations

2.3.1 Part 121, Part 125, and Part 135 Operations EFB Policy

Training/Procedures Requirement(s)

> Part 121 and Part 135 operators must have a policy that defines how the crew is expected to use the EFB. The policy must cover the specific use of each EFB function during ground operations and under all flight conditions including normal, abnormal, and emergency use.
>
> The policy must be provided in written form to flight crews.
>
> Existing policies that could be affected by the introduction of the EFB into line operations must be reviewed and modified as necessary.

Training/Procedures Recommendation(s)

> The EFB policy should also address crew resource management (CRM) and crew coordination issues.
>
> The EFB policy should also be provided to maintenance staff, dispatchers, and other employees whose responsibilities overlap with the functionality supported by the EFB.

Problem Statement

An EFB policy is a general explanation of how the EFB is expected to be used during flight operations and other activities. The purpose of a policy is to provide a framework within which procedures for using the EFB can be designed. Using a policy as the basis for procedure development will ensure that the resulting procedures are internally coherent and consistent with related procedures. Comparing a procedure to the underlying policy can aid in identifying discrepancies and conflicts with the policy. Pilots are more likely to conform to procedures developed from an explicit policy. A written description of the policy should be provided to all appropriate personnel, not just flight crews.

The EFB policy should cover issues such as crew coordination and CRM in order to address the distraction potential of EFB and to provide strategies for managing the use of various functions to prevent distraction. Strategies for crew coordination may vary depending on how many crewmembers are in the flight deck.

Example(s)

An EFB policy could be similar to an operator's automation philosophy. It could describe the value the carrier expects to gain from the EFB and the role the EFB is expected to play in line operations (flight phases in which the EFB is to be used, etc.). It could also address expected changes in the duties of maintenance, dispatch, and other staff affected by the adoption of an EFB. To be complete, the policy must address each type of functionality that is supported by the EFB. An effective policy reflects the unique operational needs of the carrier.

To address crew coordination issues, the policy should discuss who (pilot-flying or pilot-not-flying) should use the device, and under what conditions. It should also address monitoring and confirmation duties of the crew member who is not actively using the EFB. If two EFB units are on-board, the policy should also address any cross-checking that is required. If the EFB functions duplicate or overlap with other functions or information sources on the flight deck, the policy could describe the operator's philosophy for deciding which information source is primary, and which are secondary.

Evaluation Questions

- Does the air carrier have an explicit policy that addresses the use of the EFB in line operations?
- Is the policy distributed to air carrier personnel?

- Are other policies affected by the introduction of the EFB modified appropriately?
- Does the policy adequately address each specific EFB application?

2.3.2 EFB Documentation for Part 121, Part 125, and Part 135 Operations

Training/Procedures Requirement(s)

> Existing Part 121, Part 125, and Part 135 operator documentation must be modified, as necessary, to include information about the EFB.

Training/Procedures Recommendation(s)

> The EFB manufacturer should provide explanatory materials on how to use the device to Part 121/125/135 operators. These materials should provide information that is incorporated into the operator's EFB training programs.
>
> Adequate documentation should be provided to all EFB users providing guidance on how to use the EFB.

Problem Statement

The successful introduction of new equipment can be aided by the provision of adequate documentation that can be used for training purposes and as a resource for issues that may arise in the future. The EFB manufacturer should provide a starting point for developing air carrier EFB training programs (e.g., in the form of a basic user's manual). EFB information must be incorporated into existing documentation and could be provided additionally as a standalone manual.

Example(s)

Existing documentation may need to be modified to address EFB use within the larger context of flight operations (e.g., the minimum equipment list). A separate EFB handbook may also be appropriate. In either case, this documentation could include the air carrier's policy on EFB use and an overview of the functionality supported by the EFB. The documentation could also include dispatch relief and procedures, including information about which EFB functions may be inoperable, and if inoperable, what alternative sources and procedures are used.

The logic of the user interface could be described, together with the procedures for using the EFB under normal and non-normal conditions. Indications of a malfunctioning EFB and procedures for coping with a malfunctioning EFB are also important. Procedures that will be used to upgrade EFB software and content may be an appropriate topic. Finally, the document should list sources of additional information and help in using the EFB.

Evaluation Questions

- Is the documentation provided with the EFB sufficient?
- Did the air carrier incorporate EFB information into its current documentation?

2.3.3 EFB Documentation for Part 91 Operators

Training/Procedures Recommendation(s)

Part 91 operators/users should receive explanatory materials on how to use the device from the EFB manufacturer. If the Part 91 operator does not have a company-designed training program, the materials from the manufacturer should be specifically designed for training, not just a system specification.

Training/Procedures Suggestion(s)

Hands-on training with a qualified instructor may be preferred for some aspects of using the EFB.

Problem Statement

Even "easy to use," well designed EFBs may be mysterious to new users at first, or they may have features that are mysterious even to experienced users. These difficulties may produce inefficient or incorrect use of the device, potentially affecting safety of flight.

Training may not be mandated for Part 91 operators, but a training guide should be provided. Hands-on training with a qualified instructor would be best.

Example(s)

Applications where interactive data entry is required, and where the resulting computations bear a direct effect on the safety of the flight, may need more formal training than applications that do not affect the safety of flight directly. Also, training is more critical for EFBs that are used as primary sources of information.

Users who are transitioning to new aircraft or to an upgraded model of EFB may need only a differences-training program.

Evaluation Question(s)

- What materials and/or instruction are provided by the manufacturer on using the EFB?
- What materials and/or instruction are provided by the operator on using the EFB?

2.3.4 Initial EFB Training for Part 121 and Part 135 Operators

Training/Procedures Requirement(s)

> For Part 121 and Part 135 operators, training programs must ensure that users are competent in operating the EFB, in terms of both their knowledge and skills. (See AC 120-53 for guidance on developing training programs.)
>
> The curriculum (consisting of ground training, simulation, and, if needed, a flight training segment) should cover the EFB equipment, operating practices, procedures, and conditions/limitations for use. Discussion of the EFB equipment should include a description of the EFB, its capabilities and applications, a description of EFB controls, displays, symbology (including graphical icons, use of color and standard color coding), and failure modes. Discussion of EFB operating practices should be documented in written form.
>
> Some home study may be an acceptable substitute for classroom study, provided all pilots demonstrate proficiency with the system prior to flight.

Problem Statement

The introduction of new equipment places additional demands on already full training programs. To produce training that is both efficient and effective, minimum knowledge and skill requirements should be defined, and appropriate instruction techniques should be used.

Training will vary based on the variety and criticality of applications on the EFB. Training programs may have to be updated each time the EFB software and/or hardware is updated, unless the change is so small that an internal information bulletin (or equivalent) would be an acceptable substitute. The airline and its principal operations inspector (POI) need to agree on an acceptable training program.

Training may involve classroom or home study. In order to be more efficient, different training programs may be designed for completely new users (e.g., a new airline hire), users who are transitioning to new aircraft, and those who are undergoing annual continuing qualification training.

Example(s)

Training for initial users may consist of both a separate course on the EFB alone, and integrated training using the EFB in concert with other aircraft systems. For users who are already experienced with the basic device, EFB training could be integrated with more general qualification training.

Training needs for EFBs may be more critical for EFBs that are used in critical phases of flight, or those that are used as the sole means of completing flight-critical functions. For example, if use of the EFB is required during an emergency procedure, Level D training may be required.

Some topics that might be covered in a training program include:

- Company EFB policy
- Retrieving and storing the EFB unit
- Procedures for operating the individual EFB applications, and use of multiple applications at the same time
- Interactions (if any) with other aircraft systems, including all data transactions
- Typical problems that users encounter and strategies for avoiding, detecting, and correcting typical errors and faults
- Procedures for updating EFB data and/or software, and how to check whether the data are approved for use in flight
- MEL status, including paper or other backup
- Crew coordination issues

Evaluation Question(s)

- Is EFB training designed to meet defined knowledge and skill requirements?
- Is EFB training customized for the audience (e.g., first-time user versus experienced user)?

2.3.5 Evaluating EFB Proficiency for Part 121 and Part 135 Operators

Training/Procedures Requirement(s)

> In order to evaluate EFB proficiency during initial training for Part 121 and Part 135 operators, both the knowledge and skill requirements must be checked.
>
> Recurrent training for this group must include appropriate use of the EFB within the context of normal and non-normal procedures.

Problem Statement

Appropriate evaluation of proficiency with EFBs is key to ensuring that pilots achieve minimum proficiency during initial EFB training and maintain that proficiency during line operations, as evaluated through both line checks and recurrent or continuing qualification training. The evaluation of proficiency with EFBs should be consistent with the carrier's EFB policy and standard operating procedures.

AQP training, as well as some Part 121 programs, uses a series of evaluation gates that support regular testing and, therefore, early detection of weaknesses in a pilot's knowledge or skills. The number and types of evaluation gates will depend on whether the EFB training is conducted apart from qualification or continuing qualification training or whether it is integrated into existing programs. In either case, evaluating proficiency on the EFB as a part of initial EFB training involves both a knowledge and a skill component.

Example(s)

Evaluating proficiency with the EFB as a part of recurrent EFB training can take place within the context of appropriate evaluation gates. First-look and maneuver validation are appropriate for evaluating the use of the EFB while executing procedures. The use of the EFB as a decision tool and workload management aide is better addressed during line oriented evaluation (LOE).

Evaluation Question(s)

- Does the carrier's initial EFB training include evaluation of both knowledge and skill requirements?
- Does the carrier's recurrent or continuing qualification training include evaluations of proficiency with the EFB during all appropriate evaluation gates?

2.3.6 Fidelity of EFB Training Device

Training/Procedures Recommendation(s)

> The level of EFB software and hardware fidelity for training should match or exceed training requirements.

Problem Statements

The issue of what constitutes sufficient simulator fidelity for training and evaluation purposes has been of interest to the air carrier community for many years. Historically, full fidelity was assumed to be the ideal. Now, it is known that the required degree of fidelity depends upon the specific training goals. Training device fidelity is also an issue for EFBs and must also be driven by training requirements.

Fidelity requirements must be driven by the training requirements during each stage of the training process. A clear definition of the training goals should drive decisions concerning the required level of fidelity. Depending upon the training goals, different levels of fidelity may be required of the software and hardware.

Example(s)

The cost of a fully ruggedized EFB that meets all certification requirements for use on the flight deck may be prohibitive when the intended use of the device is for training purposes. Instead, users may be able to meet many knowledge requirements by substituting a standard laptop computer that runs the EFB software. The software itself must be identical to that used on the flight deck but the hardware may not need to be.

Training the user on the procedures for operating the device will require that the hardware interface be identical to the device used in flight, but the training device need not be ruggedized.

If the training is on EFB functions that are linked to phase of flight, such as integrated ECLs, the EFB may need to be modified to allow the device to be reset to different flight phases or repeat maneuvers as necessary in a non-real time manner. If this capability is not implemented, negative training may result from the EFB function being out of sync with the simulator phase of flight, causing the flight crew to intervene in unrealistic ways.

Evaluation Questions

- Does the EFB training device that is used during each phase of training provide the required degree of fidelity?
- Does it simulate the important aspects of the task conditions, and are those aspects of the tasks that are not simulated unimportant?

2.3.7 User Feedback

Training/Procedures Recommendation(s)

A formal process for gathering feedback from all personnel whose jobs are impacted by the EFB should be implemented for Part 121 and Part 135 operations. Such a process is recommended for use during design, installation, modifications, or improvements to procedures and/or training.

Feedback obtained from this process should be provided to the manufacturer to enable them to improve the system.

Training/Procedures Suggestion(s)

A representative sample of users (e.g., including line pilots, technical pilots, and training captains) should be involved in the development and evaluation of the EFB and its applications.

Evaluation at early stages of the lifecycle could involve individual interviews, group discussions and use of paper based simulations. As the development proceeds, increasingly realistic simulations of the system could be provided, for example using personal/desktop computer simulations. In the later stages of the development, before final operational use, feedback could be collected from aircraft simulator sessions.

The introduction of the EFB into a fleet may benefit from small-group tryouts of the EFB, operating procedures, documentation, and training.

Problem Statement

Developing and introducing a new piece of equipment into the flight deck requires changes to procedures, documentation, and training programs. Users are an important source of feedback throughout both development and initial deployment. The feedback should be directed to a group whose purpose is to track issues and design features, so that requests for modifications are explored and implemented as necessary.

Example(s)

A small-group tryout prior to full introduction into a fleet can be an effective way of evaluating changes to procedures, documents, and training—particularly on an early system prototype prior to finalizing the design. Rapid feedback can be obtained and the investment in staff training is minimized.

Once the EFB has been introduced, a formal process for accessing feedback from users can provide valuable information as users become experienced with the device. Pilots, check airmen, instructors, dispatchers and other personnel should be encouraged to submit their opinions and suggestions for improvements concerning procedures, techniques, documentation, problems occurring on the line, and training. Each submission should receive a formal response from an appropriate manager.

Advanced Qualification Program (AQP) carriers can use their data analysis methodology to gather evaluation information from all evaluation gates, including line checks and Line Oriented Evaluations (LOEs), to assess how well pilots are doing with the EFB.

Evaluation Questions

- Were representative users involved in the design of the EFB?
- Will the EFB be introduced using small-group tryouts? Does the tryout group include representatives from all user groups, including pilots of glass-cockpits and non-glass cockpits, maintenance personnel, and others noted above?
- Is there a formal process for gathering feedback about the EFB and its support? Will feedback from this process be sent to the equipment manufacturer?

2.4 Software Considerations

2.4.1 User Interface—General Design

Equipment Recommendation(s)

The user interface should be designed in accordance with appropriate industry guidance materials (e.g., style guides for industry operating systems, or guidance from the Society of Automotive Engineers (SAE) and RTCA).

The user interface should be designed with a consistent set of controls (e.g., buttons) and graphic elements (e.g., icons, windows, and menus). Controls that are used for different purposes should be visually distinct from one another. Functional properties of graphic elements and controls should follow standard personal computer conventions, except where there is evidence that these conventions are inappropriate for use in the flight deck environment.

Within menus (soft key, pull-down, or any other type), functions should be accessible in proportion to their frequency of use and criticality to the mission of the aircraft.

Equipment Issue(s)

During the initial design of EFB hardware, designers should consider what functions would be better handled by hardware controls (i.e., physical knobs and buttons), and what functions would be better handled by software controls.

Functions that must be accessible quickly, regardless of what application is active on the EFB (e.g., brightness controls), are more suited to hardware controls. Functions that are specific to an application might be better suited to software controls.

Problem Statement

The user interface is often the main aspect of a device that affects a user's ability to use a system effectively and efficiently. A device could have many functions, but if the user interface works poorly, users may choose not to use the system, or they may make errors (noticed or unnoticed) that increase workload and have other negative consequences.

User interfaces that work smoothly, and without concerted effort on the users part, are those that work the way users expect them to, are internally highly consistent, and have anticipated the users commonly accessed functionality appropriately.

An often overlooked, but perhaps the most important, aspect of usability is the underlying structure of the user interface. Specifically, the user interface structure specifies a template of the functions and functional logic of the product. If the functions, the logic used to access and operate those functions, and the means of navigation are consistent with existing user knowledge, users will be more likely to learn how to use the product with minimal training and find it intuitive. If the functions, functional logic, and navigation logic are arbitrary or driven by technological considerations, users will likely find the product hard to use.

Consistency is important, not just within the product, but between the product and the familiar world, the task environment, cultural conventions and expectations, industry and user interface standards, and other similar products with which the user may be familiar.

Example(s)

Functions that are common across applications should be performed in a consistent manner. For example, there should be high level similarities between the tasks of accessing a reference document, accessing a chart, or accessing a checklist.

Another example of a common function is selection of an airport identifier. Every time an airport identifier is entered, regardless of the application, or context, the same procedure(s) should be available.

Controls that are similar in functionality (e.g., those that perform actions) should be graphically similar to each other (e.g., in shape and color).

Users find the Windows and Macintosh graphical user interfaces easy to use because the interaction logic is based on a real-world counterpart that they are already familiar with: the world of paper documents, file folders, desktops, garbage cans, and so forth. It is the desktop metaphor, not just the graphics, that makes these interfaces intuitive.

Evaluation Question(s)

- Is the user interface highly internally consistent? Are there standard ways to perform common actions?
- Are the user interface, functions, and functional and navigation logic consistent with user expectations, based on their prior experience and knowledge?
- Are common actions and time-critical functions easy to access?

2.4.2 Compatibility Across Applications on the EFB and Use of Style Guides

Equipment Recommendation(s)

All applications on the EFB should be designed in conformance a style guide. If available, the style guide should be customized for the specific aircraft, otherwise the style guide could be for that specific EFB system. The practices documented in the style guides should be evaluated for suitability in an aviation environment. Note: Style guides for EFBs should also be consistent with industry standard operating systems, such as Windows™ (see reference list).

If an industry style guide is not available, developers of EFB hardware and operating systems should write a user interface style guide for application developers to explain the user interface principles and conventions for that system. These style guides should include standard practices for performing common actions (e.g., opening and closing documents, selecting and editing text, or printing) and standard user interface elements (e.g., windows, menus, dialog boxes, and system alerts). Conventions for the behaviors of the input mechanism (e.g., "single" or double-clicking), use of color, and icons/graphic elements, standard shortcut conventions, and navigation methods should also be documented.

There should be a consistent convention for the use of color and other formatting (e.g., use of underlining) across the EFB applications. There should be a standard help facility convention across the EFB applications. Soft key labels and drop down menus should also be consistent across applications.

Specific common actions that are allowed on multiple applications (e.g., launching or exiting an application, or selecting a hyperlink) should be performed in the same manner.

Problem Statement

To date, EFB prototypes have all used software customized for them by a single vendor. But in the near future, customers may purchase EFB software from different vendors, much as today one can buy software written by different companies that runs on a single desktop personal computer. If the applications are not written using the same types of graphical user interface elements and conventions, users will take longer to learn the individual software applications. In addition, users will be more likely to make errors and become frustrated with all of the applications, not just the ones that are different from the standard applications provided by the original system developers.

Manufacturers who are constructing their own EFB operating system and library of graphical routines should keep in mind that internal consistency of the system and external consistency with familiar conventions are critical to user acceptance and system usability. Style guides can greatly improve the internal consistency of applications.

Example(s)

Software style guides are common in the personal computer industry (see reference list). Manufacturers of operating systems specify the conventions they use in these style guides so that application developers can build consistent graphical user interfaces. Another advantage of style guides is that they can shorten the time to develop applications by giving software developers guidance on the correct user interface design methods.

Evaluation Question(s)

- Does the EFB software conform to any existing style guide for that system?
- Did the manufacturer of EFB hardware write their own style guide?
- Is the style guide consistent with established user interface conventions for similar systems?

2.4.3 General Use of Colors

Installation Recommendation(s)

> Colors on the EFB should be discriminable by the typical user under the variety of lighting conditions expected in a flight deck from a nominal reference design eye point.
>
> The ability to discriminate colors may also be affected by how the unit is positioned with respect to the user, e.g., whether the unit is used in the portrait or landscape mode. Each EFB should be evaluated for the effects of its positioning on how well colors can be discriminated.

Equipment Recommendation(s)

> Color should not be used as the sole means of identifying critical differences between information.
>
> If the EFB will be used away from the flight deck (e.g., outdoors, or in a home/office setting), colors should be discriminable by the typical user under the expected lighting conditions.
>
> Colors used to represent different types of data should not be user customizable. If the colors are customizable, there should be an easy way for users to return to a default color-coding scheme. Any customization that is available should not allow users to define color uses that would conflict with flight deck color standards.
>
> Red should not be used on for informational purposes; red should be reserved for signaling situations that require pilot action. (See 2.4.8 on Alerts and Reminders.)

Training/Procedures Recommendation(s)

> Users should receive training on the standard color conventions used on the EFB.

Equipment Suggestion(s)

> Upon request, the user should be provided with a legend describing the meanings associated with different colors on the EFB. Access to a legend of colors is especially important if the colors are user customizable at all.

Equipment Issue(s)

> There may be special considerations for EFBs to be used with other devices, such as head-up displays or night vision goggles, where additional lighting issues need to be considered.
>
> The display brightness setting may affect color discriminability.

Problem Statement

Ambient lighting conditions may vary from very dark during a night flight to direct sunlight on the display. Colors on the EFB display should be usable under all of these lighting conditions. For portable EFBs, discriminability of colors should be checked both inside and outside the flight deck. However, because the colors may not always be discriminable, it is also important that color not be used as the only cue to identify critical differences between data. Color should always be a redundant cue.

Because users will eventually learn to assign meanings to the different colors, and because an individual EFB unit may be used by more than one person, it is important that the assigned meanings not be customizable. Otherwise, one user may configure a color to an opposite or unfamiliar meaning, confusing a new user. If colors are customizable, users should be able to return to a default color scheme easily. In order to ensure that users understand color information, it is useful to allow users to request legend information about the colors. Users should also be aware of any standard color conventions in use and not be able to assign color schemes that would violate flight deck color standards.

Information that is displayed in colors that are not legible will cause pilot distraction at the least (as the pilot attempts to position the display for better legibility) and potentially more harmful consequences if critical information is misread, or not read at all.

Example(s)

Different font sizes may be used along with color to discriminate between different types of text data. For example, a large white font may denote the active checklist item and a small green font style could represent an completed item. If the font encodes important information, all of the fonts on the screen must be legible and easily discriminated from one another without any screen adjustments and in all lighting conditions.

Color should not be used as the only cue to identify the level of importance of text information. For example, to denote caution information, drawing in amber is not sufficient. The text should also be labeled as a caution.

Some display technologies are meant to be viewed only in one orientation, e.g., either portrait or landscape. If the software requires or allows screen content to be rotated to different orientations, the screen should be just as readable and the colors the same when the device is rotated. For example, if a chart could be viewed in either portrait and landscape mode, there should be no difference in readability, brightness, color rendering, and so forth when the device is viewed in either orientation.

Evaluation Question(s)

- If colors are used, are they all legible and discriminable under the different possible lighting conditions and positions from which the EFB will be viewed?
- If colors can be user-customized, is it possible to define color schemes that would violate flight deck color standards?
- Is color used redundantly? That is, is it possible to understand all the information being conveyed when the screen is viewed in monochrome?

2.4.4 Graphical Icons

Training/Procedures Recommendation(s)

Users should receive training on the meaning of graphical icons used on the EFB to ensure that the icons are understood.

Note: Graphical icons are software-implemented controls that are represented on the screen by pictures of limited size and resolution. They are sometimes accompanied by a brief text label of limited length.

Equipment Recommendation(s)

Graphical icons should be designed carefully to minimize any necessary training, and to maximize the intuitiveness of the icon for cross-cultural use.

Graphical icons should be accompanied by text labels. (Note: FAR 25.1555(a) requires labels for all controls unless their function is obvious.)

Users should be able to access text help information to explain meaning of graphical icons in more detail than the text label alone.

Equipment Suggestion

Using the same graphical icons as other flight deck systems can reduce training requirements and help to prevent error, especially in critical phases of flight or during abnormal or emergency situations.

Problem Statement

Graphical icons could be used to access commands from graphical menus/toolbars, or they may represent files and other system objects. Icons can be especially useful for expert users. However, they are typically small and of limited graphical resolution, so the actual object or command they represent may not be intuitively clear to untrained or cross-cultural users. Even trained users may forget the meaning of an icon if it is not used frequently, or if they are in stressful conditions.

Because of their potentially critical role, it is important that users are trained on their interpretation and it is important that the actual graphical image of the icon be a redundant, not sole, means of representing an object or command. Text information about that object or command should also be available.

One common problem in icon design is that the intended meaning of the icon is not immediately clear. There are many computer applications with icons whose forms are not obviously tied to the functions they represent. When the icon is too abstract, the user must learn and remember its meaning, and the icon is no longer useful as a memory aide. To make the user interface usable, the graphics should have obvious meanings; graphical icons in and of themselves do not ensure usability.

Example(s)

Achieving familiarity with all EFB icons should be an important goal of initial EFB training. In the event that the user forgets an icon's meaning, the EFB should provide an easy means for finding that information. One approach is to provide a textual label for the icon if the cursor lingers on that icon. Another approach is to provide a "legend" of all icons and their meaning that is available in a central location. However, ideally, the intended meanings of all icons should be so obvious that minimal training and no memorization or use of references are necessary

Standard icons have been developed for road signs (e.g., stop signs, pedestrian crossing, yield). These icons are documented in booklet from the USDOT Federal Highway Administration titled *Road User Guide for North America* (DOT FHWA-SA-99-020). The icons in the booklet are well designed in that their meanings are intuitive across cultures. Common signs are especially similar across cultures.

Evaluation Question(s)

- Does the initial EFB training adequately address icon meanings?
- Does the EFB provide easy access to help information that explains each icon's meaning? Are icons designed for ease of interpretation to minimize the need for training?
- Does the EFB use icons in a way that is consistent with other flight deck systems?

2.4.5 Multi-Tasking

Equipment Recommendation(s)

These recommendations apply if the EFB is able to run more than one application.

Under non-emergency, normal operations, the user should be able to select which of the open applications is currently active. The user should be able to identify the currently active application easily. The user should also be able switch between any one of these applications easily. When the user returns to an application that was running in the background, it should appear in the same state as when the user left that application, other than any differences associated with the progress or completion of processing performed in the background.

The responsiveness of any individual application (e.g., time to process user input or complete computations) should not suffer if all other supported applications are running at the same time.

To exit applications that have pending activities, the user should deal with these activities, either completing them, or overriding them with an extra confirmation step. The user should be allowed to switch applications even when there are pending tasks in the original application.

Some EFBs will support applications that are not directly related to flight tasks (e.g., word processor, or game). In order to discourage inappropriate use of non-flight-related functions, the system should, at a minimum, warn the user that these applications are not recommended for use in flight, and ask for confirmation to proceed when they are launched.

Equipment Issue(s)

For each application running at the same time on an EFB, it may be useful to have summary information available in the foreground, without requiring the user to activate that application. The operating system should support the ability to view basic information about an application without activating that application.

Also, it may be useful to launch some applications automatically upon system startup.

Problem Statement

Multi-tasking may be implemented and used operationally in different ways. The main priority to keep in mind is that the user must be able to keep track of which application is currently active easily in order to prevent confusion. Sometimes the user may need to switch between multiple active applications quickly. If switching is cumbersome, time-consuming, or error prone, the pilot's workload will increase. In order to avoid switching between applications often, it may be useful to be able to view some basic information without having to activate the background application.

Example(s)

One way to manage multiple applications is from a soft-key “main” menu that has a list of all available applications. Users should be able to get to this main menu with a single key press from any point in the software. The main menu should appear on the default starting screen.

Some applications, such as an ECL, or chart display, could start automatically when the EFB is turned on since they may be useful immediately. These applications should also close automatically when the EFB is turned off. The user should still be able to close them manually, with a warning to finish pending tasks and user confirmation. For example, if the user attempts to close the ECL, and there are one or more incomplete checklists, the user should deal with checklists before exiting the ECL.

For an ECL that is running in the background, it may be useful for the user to know the name of the currently active checklist, if any, in the foreground. This technique is especially helpful when the background application has time-dependent information (e.g., traffic information). For traffic information, for example, a running count of the number of other aircraft within a user-specified distance, such as 10 miles, may be useful to have in the foreground.

Evaluation Questions

- Can the user identify the current application easily? Can the user switch between applications easily?
- Is there an extra confirmation step required to get to any applications that are not flight related?

2.4.6 Responsiveness of Application

Equipment Requirement(s)

The system must provide feedback to the user when a user input is processed. Alphanumeric inputs must be drawn on the display within 0.2 seconds. If the system is busy with internal tasks that preclude immediate processing of user input for longer than 0.5 seconds (e.g., calculation, self test, or data refresh), a “system busy” indicator (e.g., clock icon) must be displayed to show the user that the system is occupied and will not process inputs immediately. (Source: 1996 SAE Aerospace Recommended Practices for Data Link Systems (ARP 4791).

Equipment Recommendation(s)

Feedback for user input should vary based on the type of input.

If an internal task takes more than a few seconds to complete and user entries are not processed immediately while the task is in progress, a progress indicator should be displayed to show the user how much of the internal task is complete so that he/she has a sense of when the full task will be completed and when processing of user input will resume.

User entries that are made while the system is occupied should be stored and processed as soon as resources are available.

Equipment Suggestion(s)

A busy indicator can be drawn *whenever* the application is occupied. If shown for only a short time, the busy indicator is not noticeable; if shown for a longer time, it will be noticed.

Equipment Issue(s)

Responsiveness may be more important for functions used in high workload phases of flight, but even less important applications should be reasonably responsive.

The responsiveness of an application may be more variable, and slower overall, if files are stored remotely and accessed via network or data link.

Problem Statement

Immediate user feedback must be provided so that the user is aware that the system has received and accepted his/her input. Without feedback, the user may try to re-enter inputs multiple times in a short interval, and he/she will become confused when the system eventually acts upon the multiple inputs. If user entries are not being accepted, this must be indicated so that the user does not attempt to make entries that are then discarded by the system. Excessive delays in access to requested information may have significant negative effects, especially during high workload phases of flight.

One common problem with progress indicators is that they are often misleading. In some applications, the estimate of progress or time remaining may be based on the number of software modules remaining to be accessed, rather than how much time the entire process will take. Consequently, some applications’ progress indicators may, for example, take a very long time to achieve 50% completion and a very short time for the rest, or vice versa. If progress indicators do not accurately represent the true time remaining or the percent of total time complete, users may learn to disregard them.

Example(s)

Examples of feedback for user inputs include:

- If the user enters a character, the character is drawn on the screen.
- If the user manipulates the cursor pointing device, its location is updated and redrawn.

- If the user select an action from a button, that action is started.

Some commons shapes for busy indicators include clocks, hour-glasses, or spinning balls/dials. Progress indicators may consist of graphical bars that are shaded in proportion to the degree that the task is complete. Text progress indicators (shown in percent complete or seconds to complete) are also acceptable.

While access to flight manuals is not always a time-critical task, documents should be loaded quickly when requested. Electronic charts may need to be available more quickly than reference information, because they may be needed during high workload phases of flight, such as while on approach to landing.

Evaluation Question(s)

- Is feedback provided for all types of user inputs within an appropriate time? Are busy indicators displayed when processing of user input is delayed?
- Are progress indicators displayed for tasks that take a significant amount of time? Are these indicators accurate and clear? Do they represent progress in a way that is useful to the pilot?

2.4.7 Anchor Locations

Equipment Recommendation(s)

> It should be easy for the user to move from any location in the EFB to an anchor location, such as the main menu, or home page for that application. The user should be able to move from the anchor location to other EFB functions easily.
>
> There should be an anchor location from which the user can move between EFB applications if more than one application is supported.

Problem Statement

In order to be useful to the pilot, the information on an EFB needs to be accessible. In order to be accessible, the pilot must know how to get to any desired data quickly, starting from any other point in the EFB. One of the standard ways to help the user orient him- or herself is to provide an anchor location such as a top-level main "menu", or a "home page." When these anchor locations are easy to access, the user can jump from one place in the EFB to another quickly and easily, while staying oriented. A common example of this is the "home" page of a web site.

If there are no anchor locations, the user is more likely to get disoriented and have trouble moving from one place to another in the EFB. This results in increased workload, distraction, and head-down time in order to navigate the user interface.

Example(s)

In a full graphical user interface, the "desktop" could be the main anchor location. It would be easy to return to the desktop from any where in the EFB functionality. From the desktop, the user could determine what EFB functions were running, and switch to any other function.

In a soft-key menu-based user interface, a top-level menu could be the main anchor location. The user would be able to go to that top-level menu by pushing a single, dedicated button at any time. Individual EFB applications, such as an electronic document viewer, or a chart display could have their own anchor pages, from which the user could access any of the functionality of that particular application, such as opening a document, or viewing the graphical chart.

Evaluation Questions

- Where are the anchor locations in the EFB software user interface? Are they obvious and easy to get to from any position in the software?

2.4.8 Alerts and Reminders

Equipment Requirement

For installed systems, EFB alerts and reminders must meet 14 CFR §§FAR 23.1322, 25.1322, 27.1322 or 29.1322 as appropriate for the intended aircraft. While the regulations refer to lights, the intent should be generalized to extend to the use of colors on displays and controls. That is, the color “red” must be used only to indicate a warning level condition. “Amber” must be used to indicate a caution level condition. Any other color may be used for items other than warnings or cautions, providing that the colors used differ sufficiently from the colors prescribed to avoid possible confusion.

Equipment Recommendation(s)

*I*t should be noted that green has been generally assigned to indicate a safe condition. In many flight decks, magenta is also reserved for special purposes, to indicate either flight data source or active flight path targets. These colors should therefore be avoided for any other purpose.

EFB alerts and reminders should be consistent with the FAA standards for electronic displays in AC 25-11 and FAR 23.1311a. International recommended guidance can be found in publications of the Joint Aviation Authorities (JAA) including AMJ 25-11 (Advisory material Joint) and AMJ 25.1322 on warnings and cautions. Additional recommendations are listed in SAE ARP 4102/4 on Flight Deck Alerting Systems and the January 1996 FAA Human Factors Design Guide for Acquisition of Commercial-off-the-shelf Subsystems, Non-Developmental Items, and Developmental Systems—Final Report and Guide (Sections 7 and 8).

EFB alerts and reminders should be integrated with (or compatible with) presentation of other flight deck system alerts.

Messages should be prioritized and the message prioritization scheme should be documented and evaluated. EFB messages, both visual and auditory, should be inhibited during high workload phases of flight.

Flashing text or symbols should be avoided in any EFB application.

During high workload phases of flight, required flight information should be continuously presented without uncommanded overlays, pop-ups, or pre-emptive messages, except those indicating the failure or degradation of the current EFB application.

Installation and Equipment Issue

Designers should consider whether the alert is necessary and where it should be displayed, particularly for EFBs that communicate with flight deck systems. Alerts could be displayed on the EFB, or on a general flight deck message display. If some messages are shown in one place, and others are shown elsewhere, there should be a clear rationale, from the crew's perspective, as to what types of messages are shown in each location.

Any use of audio alerts should be assessed in terms of confusion with other audio alerts.

Problem Statement

Because EFBs may be integrated with flight deck systems, and/or present information that is critical to flight safety, it is important to integrate flight-critical EFB alerts/reminders into the overall flight deck alert/reminder philosophy. Some of the factors to consider in the display of alerts include (a) overall necessity, (b) time-criticality, and (c) priority level within the overall context of the flight.

Because the flight deck environment places tremendous demands on the pilot visual system, audio alerts are often used. Audio is already used on the flight deck by a number of systems. Ten or more unique audio sounds, together with dozens of vocal warnings, are not uncommon on advanced automation aircraft. An audio warning system as part of an EFB should be assessed in terms of possible confusion with other systems, ease of control, and training requirements.

Example(s)

Messages that are time-critical, although they may be generated by an EFB, should be displayed on a general alerting system. Messages specific to the EFB application (e.g., "value out of bounds") should be displayed on the EFB.

It may also be appropriate to display messages with different amounts of detail both on the EFB and on the general alerting display. For example, the general alert display could show generic text such as "EFB Message" and the specific message would be shown on the EFB.

See the Terrain Awareness and Warning System (TAWS) TSO C151a for a sample alert prioritization scheme.

If the EFB is deployed during takeoff, and it has any audible alerts, it should be connected to the avionics in such a way that it respects the alert suppression logic used throughout the flight deck for takeoff, the initial stage of climb, and the final stage of descent and landing.

Yellow could be used to indicate a “caution” that a data base is out-of-date, assuming that the database can be updated sometime in the next few days.

Evaluation Question(s)

- Do the EFB alerts and reminders meet the requirements in the appropriate FARs?
- What is the philosophy for alerts/reminders?

2.4.9 Display of System Status

Equipment Recommendation(s)

> If an application is fully or partially disabled, or is not visible or accessible to the user, this loss of function should be clearly indicated to the user with a positive indicator. That is, lack of an indication is not sufficient to declare a failure condition.
>
> The immediacy of the status annunciation should be appropriate to the function that is lost or disabled. For some functions, an immediate status annunciation (i.e., an active interruption) is appropriate. For other functions, a passive status indicator that appears when the user attempts to access that function is more appropriate.

Problem Statement

There are many reasons why systems fail to operate as expected. For example, functions that require external data may fail when the that data is not received, producing a partial failure. A total failure may occur if there is a hardware fault.

The user should receive a positive indication of any system failures. A positive indicator of failure (e.g., a warning light or message that appears upon a failure condition) is clearer and more noticeable than a negative indicator (e.g., a warning light or message that turns off.) The immediacy of the status annunciation should be matched with the characteristics (e.g., importance and time-criticality) of the function that is lost or disabled.

Without a clear indication of the failure, the user may make decisions based on outdated, incorrect, or incomplete information.

Example(s)

Access to electronic charts may be lost. However, if paper backups are required to be in use, the loss of electronic charts would not require an audible (high-immediacy) alarm.

If the EFB application is integrated with other flight deck systems and this connection fails, the user should be alerted immediately to this failure. For example, an EFB electronic checklist may be designed to bring up a non-normal condition checklist upon encountering such a condition. However, if the EFB has lost its connection, it may not know of the non-normal condition and the pilot may miss an associated checklist because he/she presumed that the checklist function was working correctly when the non-normal condition began.

As another example, if the EFB provides real-time information, such as weather or air traffic clearances via some type of data link system, the user should be notified if there is a problem with the data link that precludes normal display of the data. If the link is down completely, and there is no data to display, this must be distinguished from the case where there is a blank screen because, for example, there is no traffic or precipitation in the selected region. If the link is operational in a degraded mode (e.g., the data rate is half of the normal rate so that the data is refreshed less often) this must also be brought to the crew's attention. For data link services, this requirement to notify the crew of system errors should be consistent with the Minimum Operational Performance Standards for that service and with AC-140 (see reference list).

Non-essential applications such as e-mail connectivity and administrative reports may require an error message when the user actually attempts to access these functions, rather than an immediate status annunciation when the failure occurs.

Evaluation Question(s)

- Are partial or full failures of the EFB clearly annunciated with positive indicators?
- Is the immediacy of the failure annunciation appropriate to the function that is lost or disabled?

2.4.10 Legibility of Text—Character Issues

Equipment Recommendation(s)

> The EFB should use a highly legible typeface that enables the user to quickly and accurately identify each character. In particular:
>
> a) Individual characters should not be easily confused with other characters.
>
> b) Characters with stroke widths should provide sufficient contrast between the character and the background.
>
> c) Characters should be drawn with constant stroke widths.
>
> d) Use of slanting or italic characters and upper case text should be avoided.

Problem Statement

In order for information to be quickly and accurately understood by the user, each typeface that is used by the EFB must be highly legible. Legibility is affected by such factors as the shape of each character, the width of the strokes that form each character, and contrast between the character and the background. Italic and upper case text are generally more difficult to read (i.e., they are more prone to being misread, and take longer to process even when read correctly) than plain text.

Example(s)

Sans serif typefaces do not use small horizontal strokes at the top or bottom of characters (e.g., “h” or “y”). Serif typefaces do have small horizontal strokes at the top or bottom of characters (e.g., “h” or “y”). Sans serif typefaces are typically more legible than serif typefaces on a computer screen. If a serif typeface is used, a higher screen resolution may be necessary to achieve comparable legibility.

The similarity of individual characters also affects legibility. In order to achieve a “family” appearance, some typefaces use characters that appear quite similar. Characters which are most likely to be confused are “P” and “R”; “B,” “D,” and “E”; “G,” “O,” and “C;” “l” (the letter) and “1” (the number); and “Z” and “2.”

Upper case text is more difficult to read and, therefore, should be used sparingly. It should not be used for emphasis. Slanted or italic text should be avoided for the same reason.

Evaluation Question(s)

- Are individual characters easily recognized for each typeface that is used?
- Does the typeface use strokes with sufficient and constant width to enable each character to stand out against the screen background?
- Is upper case and italic text avoided?

2.4.11 Legibility of Text—Typeface Size and Width

Equipment Requirement(s)

> The EFB must use a typeface size that is appropriate for the viewing conditions (e.g., viewing distance and lighting conditions) and the criticality of the text.

Equipment Recommendation(s)

> The January 1996 FAA Human Factors Design Guide for Acquisition of Commercial-off-the-shelf Subsystems, Non-Developmental Items, and Developmental Systems—Final Report and Guide recommends the following:
>
> a) Use a typeface height of at least 1/200 of the viewing distance.
>
> b) Use a larger typeface size for text that can be expected to be read under low-visibility conditions (e.g., some emergency checklists).
>
> c) The ratio of character height to width should be:
>
> —At least 1:07 to 1:09 for equally spaced characters and when lines of 80 or fewer characters are used.
>
> —At least 1:0.5 if more than 80 characters per line are used.
>
> —As much as 1:1 for inherently wide characters such as “M” and “W” when proportionally spaced characters are used.
>
> If these guidelines are not met, there should be a sound basis for deviation.

Problem Statement

Typeface size is a critical determinant of the ease with which text can be read. The variety of lighting conditions under which the text must be read must be considered. Equally important is the type of information being conveyed. Important information that must be read under potentially low-visibility conditions should be displayed using a larger height in order to ensure that the users can quickly and accurately read the information. Equally important is typeface width. Narrow characters can be more difficult to read.

If the typeface is to small to read when the EFB is in its normal use position, pilots may misread the text, or they may incur extra workload by the need either to zoom the display, or to re-position it to be at a closer viewing distance to make the text legible.

Example(s)

The minimum typeface size that is used must support legibility under a wide range of lighting conditions. EFB information should, therefore, be presented using a minimum typeface height of that is 1/200 of the viewing distance. For a viewing distance of approximately 31 inches, the characters must be at least .16 inch high. A larger size may be required for some applications. In particular, emergency checklists that will be used under low-visibility conditions, such as checklists used for smoke-related conditions, should use a larger size.

The recommended width of typeface characters is defined as a ratio of character height to width. Wider characters (1:0.7 to 1:0.9) are needed for equally spaced characters and lines of 80 or fewer characters. Narrow widths (a minimum of 1:0.5) may be used for lines of text having 80 or more characters. Naturally wide characters (“M” and “W”) will require a ratio as high as 1:1.

Evaluation Question(s)

- Is the typeface size easily legible under normal viewing conditions?
- Is the typeface size adequate for emergency checklists and other important text that can be expected to be used under low-visibility conditions?
- If the typeface size is smaller than recommended, what level of workload is incurred by the need to zoom or re-position the display to make the text legible?

2.4.12 Legibility of Text—Spacing for Readability

Equipment Requirement(s)

In order to make text easily readable:

a) Use a horizontal spacing between characters of at least 10 percent of character height.

b) Use spacing between words of at least one character when using equally spaced characters or the width of the capital letter “N” for proportionally spaced characters.

c) Use a vertical spacing between lines of at least two stroke widths or 15 percent of character height, whichever is larger. Vertical spacing begins at the bottom of character descenders and ends at the top of accent marks on upper case characters.

d) Use line lengths that are appropriate for the type of text (e.g., checklists)

Problem Statement

Text displayed by the EFB must be readable as well as legible. Readability is primarily concerned with enabling the reader to easily recognize words and keep the reader’s eye from unintentionally skipping to another line of text. Readability is determined by the spacing between individual characters and words, between lines of text, and by the length of the line of text.

If the spacing of characters and words is inappropriate, the pilot may misread text and/or take longer than necessary to process the meaning of the text.

Example(s)

Appropriate vertical and horizontal spacing must be used between characters to support the user’s eye in recognizing the boundaries between characters, and between words. Tight spacing between characters can cause the characters to run together while loose character spacing makes the boundaries between words less detectable. Spacing between characters must be at least 10 percent of character height while word spacing must be at least one character spacing for equally spaced characters or the width of the capital letter “N” for proportionally spaced characters.

Spacing between lines of text must be the larger of two measures: at least two stroke widths or 15 percent of character height. Vertical spacing is measured from the bottom of character descenders (that part which descends below the text line as seen in the lower-case letter “y”) to the top of the accent marks (if used) on upper case characters.

Long lines of text can cause the eye to jump to the next line. Line length is especially critical for checklists where a large gap between the challenge and response items may cause the reader to pair a response item from a different line.

Evaluation Question(s)

- Does the EFB use a horizontal spacing between characters and between words that clearly indicates boundaries between words but does not cause individual characters to blur with each other?
- Is there sufficient vertical spacing between lines to help the user’s eye avoid skipping to the next line?
- Are the line lengths used appropriate for each type of text?

2.4.13 Non-Text Display Elements

Equipment Recommendation(s)

> Non-text display elements (e.g., graphical icons and symbols) should be interpretable based on their shape alone, without relying upon secondary cues such as color.
>
> They should be designed for legibility when presented on the minimum expected display resolution when viewed from the maximal intended viewing distance. SAE ARP 4102/7 on Electronic Display Symbology for EADI/PFD gives minimum symbol visual angles as 6 millirad for primary data, and 4 millirad for secondary and descriptive data.

Equipment Suggestion(s)

> Where possible, electronic symbols should be consistent with any existing paper symbol equivalents.

Equipment Issue(s)

> In order to assess legibility of non-text display elements, the following factors should be considered: minimum requirements for pilot's visual acuity, similarity to other symbols and graphics, smallest visual feature of the symbol that distinguishes it from other symbols and graphics, the context in which the symbol will be shown (e.g., will it be one of many symbols, or stand-alone?), the importance of the information that the non-text item conveys, the conditions under which the item might be viewed, and optical qualities of the display. Display factors affecting legibility include resolution, contrast, brightness, color, and rendering techniques such as anti-aliasing (explained in 0).

Problem Statement

Non-text display elements on an EFB could include graphical icons, or other symbols, such as those on an electronic chart. These non-text items should be interpretable purely based on their shape, without relying upon secondary cues such as color. Where possible, the electronic symbols should be consistent with any paper symbol equivalents. They should be designed for legibility with the expected display resolution at the intended viewing distance.

Discrimination vs. recognition. It is easier to discriminate one symbol from another than to recognize (identify) a symbol in the absence of any context.

Some symbols may have fine detail, which is difficult to see under degraded conditions.

May be affected by zoom level. Will be affected by choice of font, font size, use of bolding, and text rotation.

May be difficult to read small characters/symbols if transferred directly from paper charts.

Position of EFB may also affect legibility of small characters/symbols.

Characters/symbols could be modified for better legibility on electronic displays with significantly lower resolution than paper.

Paper highlighting techniques (e.g., bolding) may not transfer well to lower resolution electronic displays.

Example(s)

Transferring paper chart symbology

Paper highlighting techniques (e.g., bolding, underlining)

Evaluation Question(s)

- Are graphic objects legible and interpretable at the intended screen resolution and from the intended viewing distance?

- Are any icons, symbols, and formatting consistent with how the same information is depicted on paper equivalents?

2.4.14 Supplemental Audio

Equipment Recommendation(s)

Note: Supplemental audio is defined as audio that is not associated with alerts and warnings. Supplemental audio could be verbal or non-verbal.

Users should be able to control the volume of supplemental audio. They should also be able to turn off the supplemental audio on an EFB if desired.

Objects that have associated supplemental audio should be coded such that the user knows of the associated audio before it is activated.

Supplemental audio that is audio alone (i.e., without any visual image) should have a text description available so that the user can anticipate the content of that audio clip.

Users should be able to stop the supplemental audio at any time while it is in progress.

Use of supplemental audio in flight should be avoided.

Equipment and Training/Procedures Issue

Supplemental audio may be useful for enhancing animation segments in a multimedia document. It could also be used for training purposes, especially if the sound is of high quality. However, operators should consider whether their policy should be to limit the use of supplemental audio in flight because the additional audio may interfere with higher priority audio information (e.g., radio communications). Supplemental audio may be difficult to hear in flight unless it is integrated into the flight deck audio system. Also, users may need training in how to use and control any supplemental audio functions.

Problem Statement

Supplemental audio is an optional EFB feature. It has the potential to significantly modernize the look and feel of the EFB. However, because it is an optional feature, users must have complete control over when (and whether) the audio is activated, and its volume. Because the flight deck has many other sources of higher priority auditory information, use of supplemental audio in flight should be avoided in general. The utility of supplemental audio may be highest for ground-based training purposes.

Example(s)

Video clips of training presentations, complete with supplemental audio, could be stored on the EFB. These could be accessed through a help facility.

Supplemental audio such as background music could be distracting and useless in that it does not convey any additional information to the user.

Evaluation Question(s)

- If supplemental audio is implemented, does the user have control over when, and whether, the audio is activated?
- Is supplemental audio used in flight? If yes, is the supplemental audio audible in flight without interfering with higher priority tasks?
- What is the operator's policy regarding use of supplemental audio in flight?

2.4.15 Ensuring Integrity of EFB Databases and Entered Data

Equipment Requirement(s)

> Databases that are loaded onto an EFB must be checked by appropriate methods to ensure that they are accurate, up-to-date, and uncorrupted prior to installation on the EFB.

Training/Procedures Recommendation(s)

> Data that are entered into the EFB by the pilot or by a remote source (e.g., an airline operating center) should be reviewed by the crew prior to use.
>
> As an additional safeguard, pilots should understand where the EFB data comes from, and they should be trained to review EFB data just as critically as they review data on paper. In particular, EFB data should be judged for their applicability to current operating conditions.

Problem Statement

EFBs may provide information that is important for flight safety. This information must be based on correct, uncorrupted data. If there is any question about the integrity of the data, pilots should not be making decisions based on it. Therefore, databases should be checked prior to installation on the EFB. The checks for data integrity could involve internal software checks and/or quality control by a human.

Data that are entered into the EFB by the pilot or by a remote source (e.g., an airline operating center) should also be reviewed by the crew prior to use. If these data are not checked just prior to use, it is possible that they might have been corrupted without the crew noticing.

As an additional safeguard, pilots should be trained to review data provided by EFB just as critically as they review data provided on paper. Crews should understand the source of the data and not place excessive faith in it just because it is generated electronically. Pilots should be especially careful to ensure that the data are applicable to current operating conditions.

Example(s)

An EFB might contain a database of information related to the particular aircraft it is on for the purpose of calculating flight performance. This database may be updated infrequently, but it should be checked carefully for completeness and accuracy before it is installed on the EFB.

While parked at the gate, a maintenance person may wish to browse a manual on the EFB while the crew is out. When the crew returns they may do one of the following sample procedures for reviewing EFB flight performance calculations that were completed prior to leaving the unit unattended:

(1) Clear all entered data and re-enter it themselves.

(2) Review and check all data entered from a remote source, such as Flight Dispatch, then re-enter all locally entered data. (To aid the pilot, all entered data could be highlighted on the EFB.)

(3) If a calculation is based on the locally entered data, the pilot could review all the calculation steps, even if no data entry was required; i.e., he/she could review all the raw data on which the calculations are based.

Evaluation Question(s)

- What are the procedures for ensuring that the EFB databases are accurate, up-to-date, and uncorrupted?
- What are the procedures for reviewing entered EFB data?

2.4.16 Updating EFB Software and/or Databases

Training/Procedures Recommendation(s)

> Procedures should be developed for handling EFB software and database updates to ensure that the applications and data are not corrupted in any way during the updating process. These procedures should be consistent with existing standard operating procedures.

Equipment Suggestion(s)

> Manufacturers should have a plan for how to handle modifications to the EFB after its initial purchase and installation. This plan should be understood by the customer.

Problem Statement

When an EFB arrives direct from the manufacturer, it will probably have undergone checks to ensure that the applications and data on it operate correctly. Once the operator is responsible for updating the EFB on a regular basis, however, it is important that standard practices are employed to ensure that the EFB continues to operate correctly. Flight crews and/or maintenance personnel who update the software need to use standard practices so that they do not introduce any errors or corrupt the database in other ways that would cause the EFB to fail, or degrade its performance.

It is important that the updates to EFB software/databases are made correctly and in a timely fashion. If the process breaks down, the EFB may not be usable for a given flight, or, if the information is essential, a flight delay may be incurred while the EFB equipment is fixed.

Customers expect that EFB software and databases will be upgraded and customized multiple times over its lifetime. It is important that there is clear communication between the manufacturer and the customer about how upgrades and customizations are to be performed. The responsibility for performing the EFB modifications should be clearly assigned.

Example(s)

As new versions of flight crew manuals are released, they should be loaded into the EFB. The manuals could be loaded via maintenance procedures, crew procedures, or even via automatic data link.

When a new version of an EFB software application is installed, the procedure for installation could include a final check that all files related to outdated versions of the applications are removed. A final check on the installation of the upgrade could include running a test of the new software on the EFB.

Evaluation Questions

- What is the process for updating EFB software/databases? Who will do the updates, and when?
- How will the updates be documented for the crew who has to check approval for use in flight?

2.4.17 Crew Confirmation of EFB Software/Database Approval

Training/Procedures Recommendation(s)

> A procedure must be in place for crews to confirm the revision numbers and/or dates of EFB databases and software installed on their units for each flight. Procedures should specify what action to take if the applications or databases loaded on the EFB are out of date.
>
> However, flight crews should not be required to confirm the revision dates for other databases that do no adversely affect flight operations, such as maintenance log forms, a list of airport codes, or the Captain's Atlas.
>
> The procedure for checking whether the EFB software/data is approved should be consistent across the different applications available on the EFB, and consistent with airline/operator standard operating procedures.
>
> Change information explaining the updates made in the latest revision of the EFB software and databases should be provided to the crews.

Equipment Requirement

> The EFB must provide the latest revision information to the crew upon request.

Problem Statement

Whether maintenance crews or flight crews load databases and software onto the EFB, the flight crew is ultimately responsible for ensuring that they use approved information to conduct the flight. Approved information is usually the most current, although there may be special cases where older information is still approved for use in flight. A procedure needs to be in place to make sure that this task is as simple and error-proof as possible for the crew.

Since EFB software and databases may change at different times for the different applications, making sure that approved information is in place can become even more complex if the procedure for checking approval differs between applications. Therefore, it is best to keep the procedure consistent across the different EFB functions. Ideally, approval information for all EFB software/databases would be available in one place.

Example(s)

One way of checking whether the EFB contains approved information is to provide crews with valid dates for the EFB. Crews could check that the current date is valid before each flight.

An EFB could automatically check the date and provide the pilot with a message stating whether the database was approved or not for the current flight. The automated checking routines would have to be verified themselves. For example, the EFB could check the current date and time against the EFB valid dates, but in this case, the system's knowledge of current date and time must be validated (e.g., against an independent GPS time stamp).

Evaluation Questions

- What is the procedure for ensuring that data in use is approved for use in flight? Is the procedure for checking the EFB data approval consistent with standard operating procedures?
- Can the crew request revision information from the EFB? Is the revision information presented clearly?
- Are procedures in place so pilots know what to do if the database is not approved for use in flight?

2.4.18 Links to Related Material

Equipment Suggestion(s)

Access to related information (e.g., more detailed information, or definitions of acronyms and terms) could be provided through links, pop-up information, or other similar techniques.

Equipment Recommendation(s)

If related information is accessible, a consistent philosophy should be used for determining how different types of information will be accessed. Similar types of information should be accessed in the same way. Also, if related information is accessible, it should be easy for the user to keep track of how to move between the different topics. In particular, it should be easy for the user to return to the place that he/she started from easily.

Problem Statement

While pilots are very familiar with the paper documents they use (such as charts, documents, and checklists) it is desirable to increase the usability of these documents by building in links to related information. If links are available, they may allow the pilot to obtain all the necessary information from one source, rather than requiring him/her to open multiple documents or document segments to obtain the information. Links are also helpful when the pilot does not have a focused question in mind, but rather is trying to obtain more general information.

The type of information being related should determine the access method used. A consistent access philosophy will help users to anticipate what they will find if they access linked information.

Example(s)

Examples of access methods include hyperlinks to other sections of a document, pop-up panels that provide *brief* definitions of terms and acronyms (e.g., "balloon help"), context-sensitive help, and navigation buttons or tabs displayed on the screen.

Definitions of words and acronyms can be provided through pop-up panels. The pop-up panels could be activated when a word or acronym is selected and the "help" feature is on, or they could be identified by a special character formatting and then accessed when the term is "clicked."

Hyperlinks are useful to enable the user to access additional information on a referenced topic. They are especially appropriate for supporting navigation from one location in a document to another document section that provides more detail.

Navigation buttons or tabs are useful for supporting access to complementary types of information. For example, the operations manual, which dedicates a chapter to each aircraft system, could display navigation tabs at the bottom of the screen which support access to checklists and MEL information from each system chapter.

If a consistent philosophy of access to information is implemented, all definitions could be accessed in one way (e.g., pop-up panels), and all links to other document segments could be implemented in a different way (e.g., navigation buttons). The user then expect different types of information when he/she clicks on a terms as opposed to when they click on a navigation button.

It is possible that different visual information will be relevant and useful at different display scales of electronic charts. Examples include terrain rendering, holding quadrants, and airport runways. One approach to providing flexible levels of detail would be to automatically render the information that's relevant to a particular scale but let the pilot ask for more detail of an object, perhaps by hovering over that object or selecting the object and requesting more detail from a context-sensitive menu.

Charts, or portions of charts could also be linked. For example, charts for parallel runways could be linked so that it is easy to pull up the other runway if a sidestep maneuver is requested late in the approach.

Evaluation Question(s)

- Is access to related information supported?
- Are similar types of information accessed in the same way?
- How complex is it to return to the place where the user started from?

2.4.19 Display Customization

Equipment Requirement(s)

> If the application supports customization, it must also provide an easy means by which to reset all customized parameters back to their default values.

Training/Procedures Recommendation(s)

> Any user-interface customization should be limited to pre-flight.

Equipment Issue

> The extent to which the information display can be customized must be carefully evaluated to ensure that degradations in usability, legibility and readability do not occur. It may be appropriate to limit the types and range of customization for use on the flight deck relative to that which is typically provided for a standard graphical user interface.

Problem Statement

Users may want to be able to customize the appearance of the electronic document. Certain customization features can be helpful, such as allowing the user to increase the font size. However, customization may actually result in degraded information appearance. Therefore, it may be necessary to limit what parameters may be manipulated and the range of manipulation supported.

An EFB that is installed on the flight deck will be used by multiple users, so there must be a simple command to restore the appearance of the electronic document to its default parameters. In addition, providing an easy means for restoring the default parameters will reduce the time spent re-customizing the display and minimize the potential distractions associated with customization.

User interface customization should be limited to pre-flight because it may be confusing to have the conventions change during the flight. Also, this is a low priority task that should only be done during low workload conditions.

Example(s)

Personal computers allow users to manipulate resolution, background and typeface colors, font and document size, and a host of other parameters. The flight deck environment may not be the place to experiment with this broad flexibility. Each customizable parameter should be assessed as to its potential for reducing the readability and legibility of the information presented.

Unlike most office computers, EFBs may often be used by more than one user. Customizable parameters could be stored centrally, thus reducing the amount of time spent manipulating the parameters in the first place and allowing for a single reset button that would return all parameters to their default settings.

Evaluation Question(s)

- Does the electronic document application provide an easy means for resetting all parameters to their default values?
- Can the manipulation of a display parameter produce a significant decrement in the appearance of the displayed information?

2.5 Hardware Considerations

2.5.1 Pointing and Cursor Control Devices

Equipment Recommendation(s)

> There should be a way to rest and/or stabilize the hand when actively using the pointing or cursor control device.
>
> Active areas on the display (e.g., touch screen controls) should be sized to permit accurate selection with the pointing/cursor-control device in the flight deck environment under all operating conditions (e.g., turbulence).

Equipment Issue(s)

> In choosing and customizing input mechanisms, such as keyboards or cursor-control devices for an EFB, designers should consider the type of entry to be made and flight deck environmental factors that can affect the usability of that input device, such as turbulence. The performance parameters of input devices should be tailored for the intended application as well as for the flight deck environment.

Problem Statement

Pointing and cursor control devices are used to identify and select a specific point on the screen. Some pointing devices (e.g., a track ball, displacement joystick, touch pad, and mouse) operate smoothly; they allow the user to make fine selections quickly, easily, and with a great deal of flexibility in the path they take from one place to another on the screen. Other devices, such as joy pads, which are common and personal digital assistants, are commonly used for discrete movements. They allow the user to either move up/down, or right/ left, and act like multi-directional toggle switches. Force sticks (sometimes called “top hats”) are another type of pointing device. These devices move the cursor in response to the force the user exerts, right, left, up or down. They are typically small controls that are integrated onto a keyboard.

The user will interact with EFB functions via some input device, such as a track ball, touch pad, rotary knob, keyboard, or soft keys. The input device should be matched to the type and complexity of the entries to be made, and the entries to be made will vary by the function that is being performed. If the input device is poorly matched to the task, not only are errors more likely, but the task with will take considerably more time to complete, and users will become frustrated, and potentially even distracted from higher priority tasks.

Example(s)

One simple type of input is to select a text hyperlink on an electronic document using a cursor control. More complex input, such as numeric data for performance calculations may require the use of a simple, or full-featured, keyboard. If the EFB does not support entry of free text, a full keyboard may not be necessary. Control of continuous functions, such as screen brightness, is best achieved by means of a continuous control, such as a thumbwheel or knob.

As an example of optimizing an input device, consider the case of a touch screen; the active areas may need to be larger in a flight deck environment than they would be in a stable environment to promote accurate data entry in turbulence. This will in turn impact the size of the display, and the size of the unit itself.

Boeing Co. published a paper on their efforts to design input devices for the 777 that contains good information on design of transport category aircraft input devices. (See reference list for Chapter 2.) One of their recommendations is that the dimensions of active areas on the screen be a minimum of 3/8 inches in height and width, but ½ inch on each side is preferable for operations in turbulence.

Evaluation Question(s)

- Can crews use the input mechanism accurately and reliably for the least common types of data entry without an unusual level of skill, patience, or practice?
- Can the user position the pointer/cursor mechanism (if any) quickly, reliably, and repeatedly under all flight conditions (e.g., turbulence, darkness)?

2.5.2 Hardware Controls

Equipment Requirement(s)

All physical controls must be properly labeled for their intended function.

All soft function keys that have an associated action must be labeled for their current intended function. Soft function keys that are inactive should either not be labeled, or use some kind of display convention to indicate that the function is not available. (Note: Soft function keys are physical buttons whose actions can be reassigned via software.)

Equipment Recommendation(s)

Physical function keys should provide tactile feedback to the user when pushed. If the function key records lengthy activations as separate events (e.g., key repeats), the software should filter out these events if they occur too closely together for the user to have intentionally entered them as separate actions.

The EFB display and control hardware should meet the requirements given in the January 1996 FAA Human Factors Design Guide for Acquisition of Commercial-off-the-shelf Subsystems, Non-Developmental Items, and Developmental Systems—Final Report and Guide (Section 7.4 “Controls”). This reference covers topics such as dimensions of the control surface, spacing between controls, forces required to activate controls, and appropriate displacements for displacement controls such as toggle switches.

The labels used to identify the action associated with a soft function key should be clear to the user and brief. The labels should also be used consistently throughout the software.

Soft function keys may be used to select one of several available actions. When the same set of options is accessed from different points in the software, designers should make sure that the same function appears on the same physical function key at all times.

Equipment Issue(s)

If the display glass is set inside a bezel, the depth of the bezel frame can introduce a perceived misalignment between soft key labels and physical function keys when viewing the display off-angle (i.e., parallax errors).

Problem Statement

Some examples of physical controls are push buttons, rotary knobs, thumbwheels and toggle switches. Soft function keys are physical push buttons whose functions can be reassigned to a variety of actions via software. A common example of a soft function key in the flight deck is the line select keys on the FMS CDU.

Expectations about the control’s action play an important role in ease of use. For this reason, physical controls need to be labeled so that the user knows what to expect when using them. The labels should be clear, but brief.

Many other parameters of the controls should also be designed carefully, such as dimensions of the control surface, spacing between controls, forces required to activate controls, and displacements for displacement controls such as toggle switches. If these factors are not taken into account, the physical controls could be either too difficult, or too easy to activate.

Poor design of hardware controls can increase pilot workload by requiring the pilot to check his or her entries more carefully, and by having to correct incorrect entries more often. Tactile feedback can help ensure that the pilot is aware of his/her entries.

Example(s)

When soft keys are consistently mapped with a particular action, users can associate that key’s location with that action, making the software easier to use. If a function is mapped to different keys at different times or in different states, errors may occur because the user expects the function to be assigned to the same key all the time.

Multiple entries are sometimes registered by the hardware when a user holds down a button longer than usual, or when the user's finger hits the button inadvertently (e.g., in turbulence). A good rule of thumb is to discard multiple entries that occur within 300 milliseconds of each other, which is a typical length for the time between fast, discrete, intentional movements.

It may be a good idea to dedicate a function key for functions that require quick access (e.g., return to the top level menu). Not only should that function always be on the same function key, but that function should not be used for any other purpose.

In order to keep labels clear and brief, the designer should consider whether any information is repeated often. For example, if all the labels are for access to different charts for a single airport, the airport identifier should only appear once on the page, as an overall reminder. The airport identifier should not be repeated in the label for every function key on the screen.

Evaluation Question(s)

- Are controls labeled consistently and briefly for their intended function?
- Can the user easily perform the most common types of input in any operational environment?
- Do physical keys provide tactile feedback?
- Are inadvertent multiple entries discarded?

2.5.3 Display

Equipment Recommendation(s)

The physical nature of the display screen should minimize the likelihood of becoming obscured (e.g., by repelling smoke or dust particles, and by being easy to clean).

Equipment Issue(s)

Some basic features of displays that affect their usability include:

a) Resolution
b) Physical dimensions of viewing area
c) Number of colors supported
d) Range of brightness (lowest value and highest value)
e) Off-axis readability (at what point do colors washout?)

The technology used to generate the display (e.g., active matrix LCD, or passive matrix LCD, and the type of backlighting in use) can affect the visual quality perceived by user in different ways. In some cases, there are techniques (such as anti-aliasing, described below) that can improve the perceived visual quality of the display.

Liquid crystal displays (LCDs) are particularly susceptible to poor off-axis readability. As the off-axis viewing angle is increased, different colors will washout and become impossible to discriminate. Displays of video information, which are usually of relatively constant brightness may be particularly susceptible to washing out earlier than other displays with brighter, more contrasting colors.

Most conventional LCDs are strictly back-lit, and their visibility in sunlight and glare depends on how bright the backlighting can be set. However, there is a reflective LCD technology that does not rely on backlighting for visibility in high ambient light. This display can be viewed in sunlight with the backlighting off, and can be backlit for viewing in low visibility conditions.

Touch screens are particularly subject to display degradation during normal use because finger oils accumulate on the display. The finger oils can result in distracting smudges that produce glare and strange colors caused by refraction of the backlight through them. The finger oils can also attract dust and dirt to the screen.

Consideration should be given to the long-term display degradation as a result of abrasion and aging.

The display glass is often inset in a bezel. The depth of the bezel frame can impact the user's ability to see the whole drawing area on the screen. (The edges of the drawing area may not be visible when viewing the display off-angle.)

Problem Statement

The actual technology used to create an electronic visual display can significantly affect its usability. Different display technologies are susceptible to different types of usability problems. Each display should be evaluated along many dimensions for its overall suitability for the intended functionality of the EFB.

Off-axis readability is often important for effective crew coordination. It is common for, say, a first officer to enter data into a system such as the FMS CDU, and for the captain to try to follow what the first officer is doing. Any display that is not exactly replicated for both seats should be easily viewed from either seat without requiring major adjustments to body position. Often, the pilot who is trying to watch what the other pilot is doing is responsible for continuing to fly the airplane, so leaning over the pedestal and other major posture changes are undesirable.

Example(s)

Each pixel is controlled independently on an active matrix LCDs, but not on a passive matrix LCD. As a result, images on a passive matrix display are typically a little more fuzzy and less well defined than those on an active matrix display because of how the images are generated. Also, a high contrast transition on a passive LCD can cause an artifact along the rest of the display. For example, a black box on a white background may produce gray lines that run across the display in both directions from the box because the voltage difference required to render the black box may leak across all the pixels along those rows and columns. Display flicker can also be more noticeable with passive matrix LCDs.

Anti-aliasing smoothes out diagonal lines on the display by adding pixels with intermediate color and brightness values between the figure or line and the background to fill in the gaps where the edge would appear jagged. The more colors available to the display, the more fine-tuned the anti-aliasing can be, and the smoother the resulting rendering will appear.

Evaluation Question(s)

- Does the display provide enough clarity for use of the intended applications? Consider its resolution, brightness, off-axis readability, etc.
- What kinds of artifacts can appear on the display (e.g., ghost images or lines, jagged lines, or fuzzy images)?
- Does the display continue to be usable after prolonged use in the flight deck environment?

2.5.4 Accessibility to Hardware Components

Equipment and Installation Recommendation(s)

> Hardware components that are designed for routine use by the crew (e.g., cables, cable connectors, ports, disk drives, data card readers) should be easily accessible.
>
> If they are not easy to see when in use, these hardware components should be physically oriented so that the user can use them without visual contact.
>
> If multiple cables are present, they should be color coded for ease of visual identification.
>
> Locking connectors (e.g., those that use screws or clips to secure the cable) should be usable without special tools.
>
> Cables that connect in a particular orientation should be designed to prevent insertion in any other orientation. If there are multiple cables, each cable should fit only into its intended slot; it should not be possible to insert a connector into the wrong slot.

Problem Statement

Any hardware components that are expected to be used by the crew (e.g., cables, cable connectors, ports, disk drives, data card readers) need to be robust enough for repeated, occasionally rough, use by non-experts. If the components are not robust, the hardware may fail quicker than expected under real-world operating conditions. If the components are not well designed from the user's perspective, they will undergo rougher treatment by users.

Example(s)

Connectors may be present on the EFB for access to power, or data from the aircraft. If the pilot routinely needs to engage and disengage these connectors, they need to be designed for ease of use by a non-expert hardware user.

Locking connectors are likely to be preferred for use on EFBs because they will be resistant to falling off in the aircraft environment. However, the crew may need to be able to engage and disengage the connector, and should not be required to use tools for this task.

Thumbscrews are preferred over screws that require use of a screwdriver if they need to be used by the flight crew.

Evaluation Question(s)

- What are the hardware components that are routinely used by the crew? Are they easy to access?
- Are the connectors easy to use? Consider how long it takes to make the connections, how likely errors will be, and whether any special tools are required.
- Are the hardware components robust enough for use in the flight environment? For example, will connectors stay in place after lengthy use in a vibrating environment?

2.5.5 Keyboards

Equipment Recommendation(s)

Keyboards should be chosen and designed based on the specific pilot tasks they support. QWERTY keyboards should be used for tasks that involve free text entry. Numeric keypads are best suited for tasks involving significant numeric entries.

Keyboards should provide sufficient tactile feedback of key depression to ensure that the pilot knows when the key has been actuated.

There should be a position in front of the keyboard on which to stabilize and rest the hand for reliable use in turbulence.

Problem Statement

The type of keyboard used for data entry should be appropriate for the pilots' tasks. Some examples of keyboard options include: QWERTY (full), or alphabetic; wireless or wired; full size or reduced size; key pads include numeric keypads, or arrow keys only; and finally, thumb keyboards (e.g., as seen on personal digital assistants).

For any task involving free text entry, a full size QWERTY keyboard is the best. Any departure from that, such as a reduced size QWERTY keyboard, an alphabetic layout, or a thumb-operated keyboard, involves compromises. However, if text data entry is limited to a small number of discrete entries, the compromise in usability (e.g., slower typing speed, more errors in entering text) may be justified by the increased portability of the device.

For any task involving numeric data entry, a dedicated numeric keypad is best. Any departure from that, such as an embedded numeric keypad (where the numbers are secondary functions of the alphabetic keys) involves compromises as well, again in the form of slower speeds and lower accuracy in entering data.

Any keyboard used in flight should have an adequate place to rest the palm(s) for stable operation in turbulence. The action of the keys should be firm enough to reduce the likelihood of unintended actuation, and the keys should have a positive "click" when the key actuates so there is no doubt about whether the input was made successfully or not, even in turbulence.

Example(s)

Extensive text entry requires a full QWERTY keyboard positioned for use with both hands. Less extensive data entry can be accommodated with either a QWERTY keyboard or an alphabetic keyboard. If the keyboard is not intended to be used with two hands, an alphabetic layout is often sufficient, but users may still prefer the QWERTY layout because of familiarity.

Some sub-notebook computers have reduced size QWERTY keyboards. These are acceptable to some users, but not to others.

Some PDAs and pagers have thumb-operable keyboards; these are small, usually round keys arranged in a QWERTY configuration but rounded around the center front of the device so that when the thumbs are in the center front of the case, the keys are arrayed around them.

Numeric keypads are sometimes embedded in QWERTY keyboards and accessed by changing the keyboard function or mode. However, since keys arranged in the QWERTY configuration are usually offset from each other row by row, and numeric keypad keys are usually arranged in straight rows and columns, embedding the numeric keys in the offset alphabetic keys can make it very difficult to use the numeric keys without looking, since the spatial relationships between the keys are different from the dedicated keypad configuration.

Evaluation Question(s)

- Is the keyboard appropriate for the task?
- Do the keys provide positive tactile feedback that can be felt even in turbulence?
- Is key action firm enough to resist unintended actuation?

3 Electronic Documents

The first function proposed for EFBs was support of electronic versions of the document in a typical airline pilot's flight bag, such as reference manuals and other operating documents. The goal is to convert paper documents into electronic documents while retaining, if not enhancing, overall readability and access to the data. For example, electronic documents could be cross-linked to make it easy for users to read about a single topic that is addressed in more than one document. Electronic documents are also expected to be easier to update and distribute.

Both paper-based and electronic document systems require information to be logically organized and structured to ensure the user can access and use the information with minimal effort. Poorly organized and structured paper-based document systems will not be enhanced by simple conversion to an electronic media; such information must be reorganized/structured before conversion.

Certain paper-based attributes such as tables of content, indices, and cross references can be significantly enhanced by automatic linking in an electronic media (i.e., hypertext links). In addition, electronic media can allow full text searches which enable the user to access information across multiple documents.

In Section 3.1, the type of documents that are being considered here are clarified and the many options that electronic documents might or might not support are reviewed. Considerations for electronic documents begin in Section 3.2, with General Issues. Layout and Appearance issues are presented in Section 3.3. Navigation and Search issues are presented in Section 3.4. Finally, optional (more advanced) electronic document features are presented in Section 3.5.

3.1 Background

3.1.1 Type of Documents Addressed

Pilots carry at least three types of documents in their flight bag: manuals, checklists, and navigation publications. Only manuals are covered in this section. Checklists are covered in Section 4 Approach charts, just one type of navigation publication, are addressed in Section 6. The manuals considered in this section include, for example:

- Pilot's Operating Handbook (POH), which contains information on the aircraft and its systems
- Flight Operations Manual (FOM), which contains airline policies and procedures, including emergency procedures
- Airport Analysis and Aircraft Performance Manual, which contains information about specific airports and runways
- Minimum Equipment List (MEL) and configuration deviation lists, which contain information about operational restrictions stemming from limitations in case of partial or full failure of various aircraft instrumentation and systems

The FAA mandates that these documents be on board the aircraft, approves or accepts their content, and reviews any changes. In the future, other similar documents, such as the Aeronautical Information Manual, the Federal Aviation Regulations, and Aircraft Maintenance Manuals, could be available on an EFB.

These flight manuals are primarily reference documents that are used relatively infrequently to find specific information, although they are sometimes used for studying topics in depth. The manuals are updated relatively infrequently (i.e., over a period of days, not hours). They are not used interactively in the way that electronic charts, or electronic checklists will be used, where the pilot routinely customizes the display, or enters data. Also, these manuals are not usually accessed in time-critical situations.

3.1.2 Features of Electronic Documents

Electronic documents may vary greatly from one another. They may vary in how the document is displayed, whether the view is customizable, how the user enters information and commands, how the user enters text (if at all), and what level of support there is for multimedia. All of these features are affected by the framework used to create electronic documents (i.e., the library of software routines). The framework is usually based on the operating system of the EFB device, though it may not be.

Advanced and basic operating systems are compared in Table 3-1 below. In general, advanced operating systems support advanced document features, but this is not always the case. For example, if the operating system supports windows, the user usually is given the option to reposition and resize the windows. However, it is best to examine each implementation of electronic documents feature by feature.

Advanced and basic electronic document features are compared in Table 3-2 on the next page. Display and input hardware limitations that may affect the user interface of electronic documents are also listed in Table 3-2. Not all systems will fit directly into either the "advanced" or "basic" categories. In some cases, it may be possible to support both advanced and basic functionalities (e.g., a screen may support both cursor-based input and function-key input). The categories merely illustrate the range of possibilities.

Another independent factor that affects electronic document functionality was already mentioned in Section 1: is the EFB integrated with other flight deck systems? If it is, then electronic documents that are related to a given system condition (e.g., failure of an item) could be suggested to the crew from built-in logic. In this case, the electronic document functionality is a decision support tool, not just a data-access tool.

Two examples illustrate the spectrum of electronic documents. First, consider a simple display system that shows unformatted text and static graphics displayed in a single window or frame. This system might marginally serve as in information repository, but would probably not be significantly better than its originating paper document, and could be worse. Without information being logically and visually “chunked”, neither paper nor electronic system would probably satisfy pilots needs.

A second example would be converting an existing, well-crafted paper document to an electronic page-based display system (e.g., Adobe Acrobat). This would preserve the original document’s organization and structure and additionally provide benefits of electronic media (e.g., hypertext linking, full-text search). Some drawbacks include certain topographical considerations such as typeface optimization for screen presentation, and screen size display capability.

Operating System	<u>Advanced</u>: Industry standard (e.g., Windows, Macintosh, or Unix) or equivalent proprietary system. The operating system supports a graphical user interface with windows and menus. There are standardized dialog boxes with standard interface elements, such as text entry boxes and command buttons. There are standardized dialog boxes for displaying system status and alerts, which are compatible with other types of dialogs boxes. The operating system is typically designed for use on personal/business computers outside of the aviation environment. It can run more than one software application at a time. Text formatting (e.g., changing font color, size, or underlining) is fully supported.
	<u>Basic</u>: Compatible with industry standard operating system to some degree (e.g. Palm OS or DOS). The basic operating system could be more or less compatible with industry standard. For example, the graphical user interface could be limited, or unsupported. Basic dialog boxes may be supported, such as modal system alerts or simple user entry dialogs (e.g., with yes/no responses), but complex user entry dialog boxes are not supported. Typically, these systems have multi-function keys, which are physical buttons whose functions are configurable via software. Text formatting could be limited or unavailable.

Table 3-1. Differences between advanced and basic EFB operating systems.

Display Area	Advanced: Documents are displayed in windows that can be repositioned on the screen and resized. The windows support scrolling text and color. Page layout can be formatted similar to a paper page on the window. More than one window/document can be open at a time and overlapped, with one window covering part of another window. May allow the user to customize the display in some ways. For example, windows could be resized or repositioned, or font properties could be modified if allowed.
	Basic: Either (a) or (b). Neither typically allows the user to customize the display. (a) Regions/Frames. The screen area has selectable regions/frames. The regions may support scrolling, but cannot be repositioned or resized individually. The basic display area does not support overlapped display regions. (b) No Regions/Frames. The screen area does not have selectable regions/frames. Scrolling, if supported, affects entire screen contents.
General User Input	Advanced: Users can point to any area of the screen and activate that point (e.g., by using a mouse, touch pad, or pen input). If that area is active, a change will occur; for example, a menu may drop down or pop-up, or a cursor may be moved to that position. Users may select actions via graphical (pop-up or pull-down) menus. The list of menu options is out of view until called up by user. The on-screen cursor may allow the user to select regions of text, for example, for printing or copying. The cursor could also be used to activate hyperlinks or to activate pop-up areas for definitions, help, or related information on a topic. There may be standardized dialog boxes with standard interface elements, such as text entry boxes and command buttons. There are standard practices for designing dialogs for confirmation of important actions and collecting user-entered data. Dialog boxes could be modal (i.e., no other user actions are accepted until dismissed) or modeless (i.e., other user actions are processed normally while the box is visible).
	Basic: Function keys are used to select menu items, activate commands, and navigate between menus and screens. The same buttons could move the cursor or scroll text. The user must always select from a visible list of alternative actions. (There might not be any pop-up or pull-down menus.)
Text Entry	Advanced: Users can enter free text easily (e.g., through a keyboard, or even hand-writing recognition software). The free text capability could be used, for example, to enter annotations, or to enter key words for search.
	Basic: Either (a) or (b) (a) Keypad-style text entry. Text entry is possible but usually cumbersome because more than one key press could be needed to enter a specific letter. For example, letters could be entered with 10 push buttons, configured as on a telephone. (To enter a "B", press the "1" key, which corresponds to "A", "B", and "C", twice.) (b) No text entry supported.
Multimedia Support	Advanced: Includes support for audio and visual animation, such as video clips, and/or sound recordings.
	Basic: Limited or no support for audio and visual animation. For example, the audio may be limited to a beep, or a few pre-programmed sounds.

Table 3-2. Comparison of advanced and basic electronic document features.

3.2 General

3.2.1 Consistency of Logical Structure Between Paper and Electronic Documents

Equipment Requirement

> The logical structure of an electronic document must be consistent with the hard copy version of that material, if a hard copy exists.

Equipment Issue(s)

> When converting paper manuals into electronic manuals, it may be possible to streamline the electronic document by deleting content that is not relevant to the aircraft in which the EFB will be used. The document could be customized either when the data is loaded onto the EFB, or through entry of specific aircraft information into the EFB. Integrated EFBs, which are connected to other aircraft systems, could potentially acquire aircraft-specific data directly through a data bus.
>
> When content is considered for deletion, designers should ensure that that data are not necessary in any unusual circumstances. Also, if entire sections of text are deleted, they should still be called out by heading, so that consistency with the more complete paper document is maintained.

Problem Statement

Pilots are very familiar with the logical structure of hard copy versions of required documents. They use this background knowledge when searching for information through a table of contents or index. If the logical structure of electronic documents differs from that of the paper documents, pilots may become confused and then have trouble locating material in either or both types of documents.

In cases where the operator determines that electronic documents are better designed for pilot use than the paper versions, it is appropriate to update the paper manuals. Consistency between the two documents' logical structures is required, but evolution towards a better structure for all versions is encouraged.

Example(s)

The section headings and section numbers for any reference manual should be the same in both the electronic and paper versions of the document. It may not be necessary to keep page numbers on the electronic version, as long as the content can be referenced in other ways, such as through section headings.

An example where customization of electronic documents could be useful is when there are multiple aircraft models or series that are very similar. For example, there is one paper manual for both Boeing 757 and 767 aircraft. Within this document, there are notes next to any material that applies to only one of the two types. An electronic version of this document could be configured to display only the material relevant to the aircraft model of interest.

Evaluation Questions

- Is the logical structure of the electronic document consistent with any hard copy version of that material?

3.2.2 Consistency of Electronic Document User Interface

Equipment Recommendation(s)

> The electronic document user interface should be designed consistently with the operating system style guide.
>
> The electronic document user interface should also be internally consistent.
>
> Text color and formatting should be used consistently.
>
> Consistent heading styles and formats should be used to highlight warnings and cautions.

Problem Statement

As noted in Section 2.4.2 (Compatibility Across Applications on the EFB and Use of Style Guides), internal system consistency is important for user acceptance and system usability. Consistency should be maintained both within and across applications.

The electronic document user interface should be consistent with regard to use of windows and/or frames (if implemented), use of shortcut keys, labels and terminology, and use of graphical elements such as command buttons and scroll bars. That is, the controls and visual display of an electronic document should be similar, regardless of the which document is displayed.

Example(s)

To distinguish consistently between visited and unvisited hyperlinks, unvisited hyperlinks could be identified as underlined text of one color, and visited hyperlinks could be underlined text of a different color.

Change bars, or other text formatting could be used to identify recent changes in the text.

Heading styles and formats could be used to highlight specific types of text, such as “special notes.”

Evaluation Questions

- Is the electronic document user interface designed consistently with the operating system style guide?
- Is the electronic document user interface internally consistent?
- Is text color and formatting used consistently?

3.2.3 Training Needs

Training/Procedures Recommendation(s)

> Users should receive training on how the logical structure of paper documents matches that of the electronic documents.
>
> Basic procedures for moving through an electronic document should be addressed in training. These includes how to choose a document for display, displaying a selected section, and moving between pages in the same document segment. If multiple documents can be open at the same time, training should also address how to move between documents.

Training/Procedures Issue

> Users are likely to need more training to work with electronic documents that support advanced features.

Problem Statement

To support compatibility between the paper and electronic versions of the same documents, electronic documents must implement the logical structure of the paper document (see 3.2.1). Users should understand how the electronic documents and paper documents match. If users are not aware of the logical consistency between paper and electronic documents, they may take longer than necessary to learn how to move through electronic documents because they may not realize that the inherent structures are consistent across media. Users should also understand how to access and display different segments of the electronic document(s) available on the system so that they do not have trouble getting to a desired location in the document.

More complex user interfaces allow more flexibility and support more features, but they can also be confusing and frustrating for users. In particular, users may end up in an undesired state without knowing how to recover. Therefore, it is expected that more advanced electronic document applications will require more training overall.

Example(s)

Electronic documents may have a table of contents similar to the paper document. The user could recognize the document's logical structure from this table.

More sophisticated functionality will require sufficient training to enable users to benefit from the functionality and protect them from getting distracted or frustrated. For example, users will need to understand how to customize documents if customization is allowed. More complex navigation and search techniques will also add to the training curriculum.

Evaluation Questions

- Does the training program provide adequate instruction in how to move through an electronic document?
- Does the training program adequately cover how to use the advanced features of the electronic document? Do users know how to avoid using advanced features if they so choose?

3.3 Layout/Appearance

3.3.1 Visual Structure

Equipment Issue

The visual structure of a document can significantly affect its readability and ease of comprehension. Factors such as font choice, text length, spatial organization, and amount of white space all affect the visual structure of the document. Designers may want to base the visual structure of an electronic manual on the hard copy version of that manual, but the two do not have to be identical. In fact, some aspects of the hard-copy visual structure (e.g., font style and size) may need to be modified for electronic displays.

Equipment Recommendation(s)

If frames are used, designers should display similar types of information in the same spatial frame.

Note: Frames are selectable regions of the display that may support scrolling, but cannot be repositioned or resized individually like windows.

Use white space to separate sections of text.

Where possible, data should be formatted into short segments, each of which communicates one clear point.

Problem Statement

Electronic documents need to be designed for ease of reading. Readability is affected not only by how legible the individual characters or words are, but also by how well the visual structure matches and reinforces the logical structure of the concepts in the material.

Example(s)

Short text segments are easier to comprehend than long text segments. Long segments of plain text are difficult to read, even if the font is well chosen. This visual structure should match the logical structure of the document in that each short text segment should be focused on communicating one clear point. Ideally, each text segment would be visible in its entirety within the display area of the EFB, so that the user does not have to access off-screen text to comprehend the point.

Use of frames can improve readability if frames are used consistently. For example, consider the case where the screen is divided into three frames. The upper half of the screen is one frame, and the lower half is divided into two equal sized frames. The top frame could be used to always display the main text of the document. The lower left frame could display a list of related links for navigation, and the lower right frame could always show related figures and/or tables (i.e., detail information).

Header and footer information that contains a brief description of the section heading can be useful for orientation.

Portable Document Format (PDF) documents, which capture the visual structure of the printed page, may need to be optimized for electronic presentation rather than just copying the paper version. For example, font choices may need to be modified for legibility on an electronic display.

Evaluation Questions

- Does the visual structure of the electronic document match and reinforce the logical structure of the document? Is white space used to separate sections of text? Are text segments short?
- Are frames (if available) used consistently?

3.3.2 Minimum Display Area

Equipment Recommendation(s)

> The manufacturer of an electronic document application should identify and specify the minimum display area necessary to view documents.
>
> Operators should meet the minimum display area requirements suggested by the manufacturer for both training and operational use of the electronic document application.

Problem Statement

In constructing the visual structure of an electronic document, the designer will have to assume a minimum display area. This assumed size will determine the smallest available space for structuring the data. Designers will make choices about the visual structure (e.g., font size and white space) based on this minimum display area. While the visual structure may transfer to a larger screen area without difficulty, it is not likely to work properly on a smaller display area that violates design assumptions.

Example(s)

If an operator intends to use the same electronic document software on EFBs with different display areas, they should ensure that all the different EFBs meet the minimum display area requirements suggested by the manufacturer of the electronic document application.

Evaluation Question(s)

- Does the manufacturer of an electronic document application specify a minimum display area?
- Does the EFB display intended for this application meet the minimum display area suggestions?

3.3.3 Off-Screen Text

Equipment Requirement(s)

> If the document segment is not visible in its entirety in the available display area, the existence of off-screen content must be clearly indicated in a consistent way.

Equipment Recommendation(s)

> For some intended functions, it may be unacceptable for certain segments to not be visible. This should be evaluated based upon the application and intended operational function.
>
> If part of the document segment is off-screen, the following information should be constantly be available to the user:
>
> - How long the document segment is
> - How far in the document segment the currently displayed information is

Problem Statement

Documents that will be on an EFB are lengthy and complex. However, they can be broken down into natural segments, such as different sections and subsections. Still, it is possible that a single document segment will be too long to be displayed in its entirety within the available display area. Users then must be made aware of the existence of off-screen content. Plus, the software should be designed to assist users in managing what text is in view and what text is out of view.

With a paper document, the pilot can look ahead to check its length and they can browse or scan the entire document to orient themselves. On an electronic display, it is useful to convey the length of the document, either graphically or numerically. One way of helping the user to orient him/herself is to convey how far in the document the currently displayed information it.

Example(s)

If the document is implemented in terms of discrete “pages,” then the current page and the total number of pages can be indicated using a convention such as “1/3,” where the first number is the current page, and the last number is the total number of pages. Arrow buttons can also be used to indicate whether there are more pages preceding or following the page currently in view.

If the document is implemented on a scrolling window, a side scroll bar can convey all the required information. A graphical box or bar would represent the location of the currently displayed text in relation to the length of the document.

More sophisticated displays for user orientation, such as an outline view, can also be very helpful for user orientation.

Evaluation Question(s)

- Is the existence of off-screen text indicated clearly? Is the existence of off-screen text indicated in a consistent way?
- Does the software indicate how long the current document segment is and the position of the currently displayed information relative to the entire length of the segment?

3.3.4 Active Regions

Equipment Requirement(s)

> Active regions must be clearly visually highlighted.
>
> Note: Active regions are regions to which special user commands will apply. The active region could be text, a graphic image, a window, frame, or other document object.

Training/Procedures Requirement(s)

> Users must know how to activate and deactivate regions.

Training/Procedures Recommendation(s)

> Users should know the basic special commands are available for different types of active regions.

Problem Statement

It is often necessary to specify an active region to which special commands will be applied. For example, a text string might be selected for copying into a search query, or a window might be activated in order to bring it to the front of other windows on the screen. Active regions are also useful for selecting between frames on a frame-based visual display. The information in the active frame would respond to update commands entered by the user.

While active regions are not a required feature of electronic documents, if they are supported they must be clearly indicated and users must know how to use them. If the user does not know how to use an active region, he/she will have trouble applying special commands to the intended object. If the user does not know that a particular region is active, he/she may enter inappropriate commands and become frustrated when these commands are not processed as expected.

Example(s)

Active text could be highlighted using reverse video. Some special commands that might apply to active text include copying and deleting. Note that a sophisticated input mechanism, such as pen input, is required for text selection.

Active windows and frames could be highlighted with special borders. Once highlighted, the window would appear in the forefront (if multiple windows are supported). Only the active window would respond to scrolling, repositioning, or resizing commands. A highlighted frame could respond to scrolling commands, but might not be movable, or resizable.

Evaluation Question(s)

- Are all types of active regions clearly highlighted?
- Are users trained in how to activate and deactivate regions?

3.3.5 Display of High Priority Information

Equipment Issue

> Some parts of an electronic document may contain high priority information that might be accessed during critical phases of flight. Because the consequences of user error may be more significant under these conditions, designers may want to apply more generous standards for legibility and readability to high priority information, such as a larger typeface and more spacing between lines.

Problem Statement

Although electronic documents will primarily be used during low-workload conditions, it is possible that some parts can be expected to be used during critical phases of flight, which hold a greater potential for human error. The contents of electronic documents could be reviewed to identify those sections which are more likely to be accessed under conditions that increase the potential for error, the occurrence of which may produce more significant consequences. If more generous standards for legibility and readability are applied to high priority information, the potential for error could be reduced.

Example(s)

The limitations section, which may be found in the Flight Standards Manual, is one example of a section that might benefit from the application of visual structure that reduces the amount of information displayed at one time. A larger typeface, more spacing between lines, and the use of additional white space between chunks of information could reduce the risk of misreading key information.

There may also be more sophisticated ways of addressing this issue. For example, an electronic document application that is integrated with other flight deck systems could dynamically highlight relevant information on the document.

Evaluation Question(s)

- Are more generous legibility and readability standards applied to high priority information in the electronic document?

3.3.6 Figures

Equipment Requirement(s)

At a minimum, the electronic version of a figure must be able to display all of the content of the paper version. The user must be able to view the overall figure at one time, even if not all the details are readable in order to get an overview of the figure. The user must also be able to read all the details in the figure, although not all of the figure may be visible when the details are readable.

Equipment Recommendation(s)

Depending upon the size and complexity of the figure, and the available display area and resolution, the user may have to manipulate the figure to (a) bring areas of the figure that are out of view into view, or (b) make readable details of the figure that are not readable otherwise. The additional workload of manipulating figures is undesirable, so figures should be displayed in their entirety with all details readable whenever possible.

Each figure should have descriptive text information associated with it. This text should be available even if the figure is not displayed.

Equipment Issue

Figures could be designed to take advantage of the electronic medium in many ways. However, more flexibility in the manipulation of figures increases the complexity of using the software, which in turn impacts user training needs. Also, more flexibility in the manipulation of figures may actually distract users from understanding the actual content in the figure.

Advanced electronic figures may contain complex, variable, dynamic, and/or user-customizable data. These figures need to be evaluated especially carefully to ensure that any there are appropriate means of catching any potential errors in the data.

Problem Statement

Figures can be used for various purposes. Graphs are a type of figure. They illustrate relationships between variables. Graphs can also be used as a source for data for calculations. Other figures are representations of relationships between components of systems.

In paper form, figures are drawn so as to be usable for one or more purposes. The user may be interested in either the detail information in the graphic, the overall schematic information in the graphic, or both. The electronic version of the figure must capture all the content of the paper version, which includes both the details and the overall schematic information. However, there may also be additional workload and training needs that arise from the need to configuring electronic figures for maximum usability. Designers should consider these tradeoffs when implementing more complex features for electronic figures.

Example(s)

In order to load data more quickly, the figure may not be displayed until specifically called up. The associated text information should describe the contents of the figure so that the user knows whether they want to call up the actual figure.

Some ways in which figures could take advantage of the electronic medium include interactivity and customization. For example, figures could be interactive in that the user could specify which "layers" of the drawing they wanted to be visible or not, in order to understand complex relationships. A graph could also be interactive in that the user could select parameters for producing the plot.

A electronic document application that was integrated with other flight deck systems could also produce custom graphs or figures relevant to the current situation. For example, if the weight of the aircraft is known, graphs and figures could show data that apply for that aircraft configuration.

Evaluation Question(s)

- Can the user view the entire figure at one time? Can the user configure the display such that details of the figure are readable?

3.3.7 Tables

Equipment Issue

Because of screen resolution limitations, translating tables from paper to electronic format may require modifications to their design to ensure that users can quickly locate target information contained in the tables.

Problem Statement

Tables typically provide a lot of data in a relatively compressed space. Borders and lines are often used to help the reader visually organize the information correctly. The comparatively low resolution of EFB screens, as compared with paper, may require that the design of existing tables be reconsidered to ensure that comparable readability is achieved.

Table size may also need to be reconsidered. Paper tables may utilize the full height and width of a standard page size. EFB screen size may be significantly smaller. A larger type size may also be required, which may require rethinking of how much data can be supported by an individual table.

Example(s)

Additional white space may be required to clearly separate individual table elements from each other and also from neighboring borders or lines. Placing column and row names in bold can help the user to interpret table information more efficiently.

If the electronic document application is aware of the aircraft systems' status, it may be possible to customize and reduce the information in a table such that only the relevant data is displayed. For example, if the weight of the aircraft is known, or the ambient temperature is known, data that apply only to those and similar conditions could be displayed.

Evaluation Question(s)

- Are the tables included in the electronic documents as readable and as usable as their paper counterparts?

3.4 Navigation and Searching

3.4.1 Moving to Specific Locations

Equipment Recommendation(s)

> If the electronic document application supports links, entries in the document table of contents and indices should be linked to the corresponding locations in the text. Cross-references should also be linked to each other, both within and across documents.
>
> If the electronic document application supports user customization, users should be able to configure and manage their own bookmarks to selected locations in the text.
>
> The electronic document application should keep track of the most recently visited locations in the document and allow the user to select from this list to return quickly to a recent location.
>
> The user should be able to cancel a movement by returning to previous location in one step.

Problem Statement

The manuals that pilots use are typically lengthy documents. It is important that users be able to navigate quickly to important locations within these lengthy manuals. Key locations in the document include the beginnings of each new section, which are listed in the table of contents, cross-references, and index entries. Each of these types of information can and should be linked to the appropriate location in the text. Other key locations in the manuals include recently visited locations and entries in the indices.

Because users often find themselves revisiting certain parts of an electronic document, it is also desirable to implement customizable electronic "bookmarks." These bookmarks would be set and managed (e.g., renamed or deleted) by the user.

Sometimes users will make a mistake and unintentionally move to a location. For these cases, the user should be allowed to cancel the movement and return to their previous location in one step.

Example(s)

Hyperlinks to different locations in the text are one way to move about a lengthy document quickly. Another way of moving about the document could be by selecting a location to move to from a list. For example, the last five visited locations could all be listed in one place (a "catalog" page), and the user could select which of these locations to move to by selecting one from the list. The selection need not be done by a pointing device. Selection could be accomplished through soft keys, which change the selected location.

Evaluation Question(s)

- Are the table of contents and indices linked to the corresponding locations in the text?
- Can users customize their own bookmarks to specified locations in the text?
- Can the users quickly return to recently visited locations in the text?

3.4.2 Managing Multiple Open Documents

Equipment Requirement(s)

> If the electronic document application supports multiple open documents, the system should indicate which document is active, and display that indication continuously. Also, under non-emergency, normal operations, the user must be able to choose which of the open documents is currently active.
>
> Note: The active document is the one that is currently displayed and responds to user actions.

Equipment Recommendation(s)

> If the electronic document application supports multiple open documents, a master list of all open documents should be available.

Equipment Suggestion(s)

> Access to a document can be provided through the master list of open documents.
>
> If the display area is large enough, it is useful to be able to arrange multiple open documents such that text from more than one document is visible at the same time.

Problem Statement

If the electronic document application can support multiple open documents, the user will need assistance in managing these documents, or else they may become confused about what document they are using because the visual structures of the documents may be very similar. In particular, the user must keep track of which documents are open, and which of these is the currently active document. Document titles help the user manage multiple open documents. The user must also be able to move between the open documents quickly. That is, the user should be able to activate an open document from a list of open documents, rather than from a list of all available documents

Example(s)

If the electronic documents are running on an industry standard windows-based GUI, document titles should appear at the top of the window frame by convention. The different documents would be selected by activating the particular window that contains the document of interest.

The user may want to open both the POH and the MEL in order to see some cross-referenced items. He/she may want to arrange these two documents such that the top half of the screen shows one document, and the bottom half shows text from the other.

Evaluation Question(s)

- If multiple open documents are supported, is the title of the active document shown continuously? Can the user easily choose which open document is active?
- Is a master list of open documents available?

3.4.3 Searches

Equipment Recommendation(s)

The electronic document application should support multiple search techniques. Some options include searching by:

- key word
- links to text (e.g., via cross-references or a table of contents)
- graphical links (e.g., look up the function of a switch based on its location in the flight deck)
- header/footer information (i.e., brief topic information).

Equipment Issue(s)

If key word search is implemented, the EFB must support entry of free text, preferably via key board rather than soft keys. Also, designers will have to consider the design of a query language. Complex query languages may have training implications. Also, designers will have to consider how the user will move between multiple hits from a key word search.

Problem Statement

One of the advantages that electronic documents can have over paper documents is the ability to search a lengthy document quickly. With paper documents, search is conducted through section headings, or indices. There are other options that can be implemented electronically, such as key word search, and text and graphical links. These electronic search techniques can be very effective when the user is conducted a very well specified search. Browsing header/footer information can be very effective when the object of the user's search is specified well enough for other types of searches.

Example(s)

To find definitions for various levels of turbulence, the user could do a search on the keywords “turbulence” and “definition,” or he/she could search via links from the table of contents of the flight operations manual.

Evaluation Question(s)

- Are multiple search techniques supported in the electronic document application?

3.5 Options

3.5.1 Printing

Equipment Recommendation(s)

Users should be able to select the subset of information they wish to print, including individual sections and individual pages.

The visual structure of the printed document should match the visual structure of the electronic document.

Equipment Requirement(s)

The electronic document application must clearly specify which pages or document sections have been selected for printing.

The user must be able to immediately terminate a printing session if a large printing range has been selected.

Problem Statement

Users may wish to have a hard copy of some portion of an electronic document. If available, the printing option should enable users to select, as precisely as possible, the subset of information of interest so that the user is not inundated with irrelevant material. In addition, users must be able to terminate a long print job in the event that an error has been made, so that the user can quickly return to the application to print the correct section.

Example(s)

The printing option should allow users to choose between printing either a page range (including a single page) or one or more sections. The print window must clearly indicate the print range that has been selected. To help ensure that the correct pages have been selected for printing, the printed version should closely correspond to the electronic version in terms of the subset of information that is printed is identical to the information displayed electronically.

In the event that an incorrect page range is selected, the user must be able to immediately terminate the printing session if more than a few pages have been selected for printing. Otherwise, the printer will be temporarily unavailable for further use and paper will be wasted.

Evaluation Question(s)

- Does the EFB allow users to choose the subset of information to be printed?
- Does the printed version correspond to the electronic version?
- Does the EFB clearly specify the subset of information that has been selected for printing?
- Can the user immediately terminate a print job that is larger than a few pages?

3.5.2 Animation

Equipment Requirement(s)

> If animation is supported, the user must be able to start and stop the segment. The user must be able to stop the animation at any time, even if the segment has not ended.
>
> Also, there must be supporting text to describe and support the animation. This text must be available even if the animation is not currently running.

Equipment Recommendation(s)

> Animation should only be used to highlight and explain important relationships. It should not be overused.
>
> If the animation has associated supplemental audio, control of both the audio and video should be integrated.

Problem Statement

Animation can be a powerful aid to visualization of complex relationships. It is especially useful for training or study of new, or very detailed material. In these situations, the user must focus attention on the animation for it to be of value.

Because of the need to focus attention on complex animations, its use in flight may need to be limited. At the very least, the user must be able to interrupt any animation in progress, in order to quickly change to higher priority tasks. Also, supporting text must be available to preview the content of the animation. In other words, the user must not be required to start the animation in order to determine its contents.

While animation can be beneficial for specific purposes, overuse of animation should be discouraged. Too much visual movement on the screen can distract the crew from higher priority tasks.

Example(s)

Animation could be implemented to show how parts of a complex mechanical system fit together, or as part of a training tutorial on use of the software.

Animation should not be used to highlight company logos.

Evaluation Question(s)

- Can the user control when the animation begins? Is the animation interruptible?
- Is there supporting text for the animation that identifies its contents without running the segment?

3.5.3 Making Notes

Equipment Issue(s)

> Paper documents are customizable in that users can make notes and highlight information of interest to them. Adding these customization features to the electronic document functionality could also be useful. The utility of this feature may be constrained, however, if users do not have access to their own notes while using an EFB. To ensure that the users can view their own notes, they may have to enter the notes on a personal EFB, or their notes may have to be accessible through a server that communicates with all EFBs.

Problem Statement

One of the advantages of paper documents is the ability for the user to underline, scribble notes in the margins, and otherwise utilize the document to record their own information. Users would benefit from having a similar capability with the electronic document function. However, the EFB may not be a personal unit, in which case, the notes may not be very useful to the other users.

The extent to which a notes feature would be useful will be determined in part by the company policy on EFB use. EFBs that are used only on the flight deck may benefit less from this feature in that users would have access to these notes only while on that specific aircraft.

Example(s)

The electronic document function could provide the capability to select chunks of text that could be highlighted in a fashion similar to underlining in a paper document. Similarly, a location in the text could be selected and a notes feature utilized to allow the user to record their own notes. Retrieval of notes could take place in two ways. First, access to the set of all notes that have been recorded could be supported. Second, a visual indicator could be placed in the location from which the note was created which would then be used to access the individual note that was created for that location. It is possible that these notes could be stored in a central ground-based server that would allow upload to the specific EFB that will be used by the note creator for each flight. If the server is used to store other information "owned" by that user, this might be useful to do.

Evaluation Question(s)

- If the electronic documentation supports note taking, can users always access their personal notes?

3.5.4 Decision Aid/Automatic call-up of Data

Equipment Issue

> The integration of an EFB with other flight deck systems may enable electronic documents to serve as a decision aid. Consideration should be given to integrating electronic documents into closed-loop systems to provide users with immediate access to information that can support more effective flight management.
>
> Although decision aids can have value in supporting more effective decision making, they can also have the unintended consequence of excessive reliance, where the crew may become complacent about reviewing the suggestions made by the system.
>
> Note that, if the EFB is used as a decision aid, its software and hardware may need to meet more stringent reliability and availability criteria than otherwise. A formal safety analysis may need to be conducted.

Problem Statement

Integrating the EFB with other flight deck systems could allow the electronic documentation application to customize its information based upon current flight conditions. Doing so can help to reduce crew workload by reducing the amount of information the crew must consider. An unintended consequence can be complacency where the crew relies on the decision aid to select information for review without sufficient crew involvement.

Example(s)

"Awareness" of aircraft system status could enable the electronic document application to display only the subset of data in a table that applies to the current situation. For example, knowing the fuel burn rate would enable the decision aid to list only the candidate airports within range if the crew needed to divert to a different airport.

Several approaches can be taken to mitigate problem of complacency. First, the decision aid could offer several options rather than a single answer; doing so would encourage the crew to review the information needed to select an option. A second approach is to require the user to make the decision first, then have the decision aid review the soundness of that decision.

Evaluation Question(s)

- Does the decision-aiding function mitigate the risks of crew complacency?

4 Electronic Checklists

Electronic checklists (ECLs) are a logical application for EFBs as well. In Section 4.1 below, electronic checklist concepts and terms are explained, as well as many of the potential benefits that they offer. Guidance statements for ECLs are presented in Sections 4.2, 4.3 and 4.4. Section 4.2 covers how checklists are accessed. Section 4.3 covers how individual checklists are completed. Optional ECL features are discussed in Section 4.4. All of these issues are important from an Equipment perspective, and some have implications for Training/Procedures.

Open Issues:

This guidance was not included in the EFB AC. People felt in belonged in AC120-64, on ECL. What are the plans for getting this guidance to the right people?

What is the policy regarding paper backups for ECL? AC120-64 says backups are required, but 120-76 provides a process for reducing paper in general; does that apply to checklists as well?

Should we cover airline customization/modification of ECL?

What about availability of ECL during emergencies? Should ECL be available during all power and environmental conditions? If not, must have a backup paper checklist?

Is training required on switching between ECL and paper checklists, if that is possible?

4.1 Background

Effective use of checklists is a critical component of the pilot's job. Failure to complete a checklist has been implicated as a key contributor to several major accidents, reinforcing the need to present electronic checklists in such a way that pilots are encouraged to perform and complete them in a timely fashion.

Electronic checklists (ECLs) are a relatively recent addition to the flight deck environment. The benefits they provide depend upon the extent to which they utilize the advantages of the electronic medium. ECLs can simplify the process of accessing desired checklists. The simplest ECLs may be no more than a digitized, static version of paper checklists but ECLs with increased functionality will be much more desirable to users.

There are three significant features that can greatly enhance ECL functionality. First, the ECL could support sequencing of checklists. These sequences can be of three types:

- Implementation of the normal sequence of use. Because normal checklists are performed in a fixed order, the EFB can be programmed to display checklists in the prescribed order. This capability helps to remind the crew of the next checklist they need to accomplish.
- Implementation of embedded checklists which are accessed from a "parent" checklist. The user could break away from the parent checklist and move to an embedded ("child") checklist which, upon its completion, returns the user to the parent checklist.
- Access to related checklists on a need basis. Some non-normal conditions require the performance of multiple checklists. For example, a non-normal condition such as a power plant failure may require that a second checklist be used to accomplish a single-engine landing. Direct access to the second checklist can be supported from the first checklist. This capability helps to lead the crew through all of the checklists they need to complete, which offers significant task management benefits.

Coupling the ECL with aircraft systems can introduce additional benefits that reduce the crew's workload. During the performance of normal checklists, a closed-loop ECL can monitor crew performance of some items. Detection of a non-normal condition enables the ECL system to produce the required checklist at the crew's request. Considerations that address checklist access are described in Section 4.2.

A second useful feature of advanced ECLs would be an ability to indicate the status of individual checklist items and the checklist as a whole. In addition to being either active or inactive, a checklist item could be uncompleted, deferred, or overridden. A deferred item is one that the crew has skipped but intends to complete at a later time. An overridden item is one that the crew does not intend to complete. Finally, for checklist items presented by a closed-loop system, a checklist item can be either sensed or not sensed. A sensed item means that the ECL is able to detect when the crew has correctly completed the item.

An ECL that keeps track of item status can support additional functionality, such as indicating the completion status of the checklist as a whole in order to prevent the crew from closing an uncompleted checklist. Checklist item status and checklist completion functionality offer significant value in protecting crews from the deleterious effects of distraction. Considerations that address checklist and checklist item status management are described in Section 4.3.

Finally, ECLs are capable of providing additional functionality not available with paper checklists. For example, they may incorporate access to supplemental information such as clarification of the meaning of a checklist item or linked calculation worksheets. Also, ECLs can provide additional support for task management through the implementation of task reminders, which remind the crew to finish tasks that take significant time to complete. Considerations that address the use of these optional features are discussed in Section 4.4.

4.2 Call-up/Access

4.2.1 Checklist Scope

Equipment Requirement(s)

> All checklists that belong to a category that is supported by the ECL must be available on the ECL.
>
> Can this requirement apply to Part 91? (Because checklists are completely user-configurable in some cases, the manufacturer/applicant may not have any control over this.)
>
> If an ECL-supported checklist requires access to a checklist that is not supported, the ECL-supported checklist must indicate the location of the unsupported checklist in the paper document.
>
> Note: Checklist categories typically include: normal, abnormal, emergency, and supplemental.

Training/Procedure Requirement(s)

> Flight crews must be trained to know which checklist categories the ECL supports.

Problem Statement

An ECL that does not include all of the checklists that belong to an ECL-supported category can create confusion and lack of trust in the system when crew members attempt to find a checklist that is not in the ECL. Excluding an entire category of checklists should not create confusion, such as using paper versions of the QRH together with electronic versions of the normal checklists.

Example(s)

Providing all of the checklists in a supported category removes the possibility that crews will waste valuable time attempting to find an unsupported checklist. If a supported checklist requires subsequent use of an unsupported checklist, the location of the unsupported checklist must be provided in the electronic checklist. Listing the paper location replaces a hyperlink or other electronic support that would otherwise be provided if both checklists were accessed from the ECL.

Evaluation Questions

- Does the ECL include all checklists for each supported checklist category?
- Is the location of the paper checklist provided in all electronic checklists that require subsequent access to an unsupported checklist?
- Is training provided that addresses which checklists are supported?

4.2.2 Accessing Normal Checklists

Equipment Requirement(s)

> If the ECL supports normal checklists, they must be accessible in accordance with the normal sequence of use during line operations.
>
> Can this requirement apply to Part 91? (Because checklists are completely user-configurable in some cases, the manufacturer/applicant may not have any control over this.)
>
> What is the policy for Part 121/135? (I don't' see any guidance on this point in AC120-64.)
>
> Normal checklists must also be individually accessible at all times.

Problem Statement

Normal checklists will be accessed during line operations, and may also be accessed for review. Their primary use is to ensure proper aircraft configuration at critical points during each phase of flight, including pre- and post-flight. ECLs must present checklists in the normal sequence to prevent the crew from skipping a checklist by mistake.

Users must also be able to access individual checklists at any time should they desire to review a specific checklist.

Example(s)

Normal checklists are typically performed in a fixed order, so the ECL may be designed to call up the next checklist automatically after the completion of its predecessor. With this feature, the crew would not be required to locate and access the next checklist.

For closed-loop systems, all checklists could be automatically displayed in response to the occurrence of appropriate system-based triggering conditions. A tie-in to aircraft systems means that system changes could determine which checklist to display at any given time.

Access to individual checklists could be supported from a "table of contents," which could be a menu or list of checklist titles that are hyperlinked to the actual checklists. The organization of the contents list should be consistent with that used in the FAA-approved flight manuals.

Evaluation Questions

- Are normal checklists presented in order during line operations?
- Can each normal checklist be individually accessed easily?

4.2.3 Accessing Non-normal Checklists

Equipment Requirement(s)

> If the ECL supports non-normal checklists, access to individual non-normal checklists must be supported at all times.
>
> Can this requirement apply to Part 91? (Because checklists are completely user-configurable in some cases, the manufacturer/applicant may not have any control over this.)
>
> What is the policy for Part 121/135? (I don't' see any guidance on this point in AC120-64.)
>
> When a non-normal condition is detected by a closed-loop ECL during line operations, the ECL must alert the crew that a checklist applies to this condition. The ECL must only call up the appropriate checklist when commanded by the crew.

Problem Statement

Like normal checklists, non-normal checklists will be accessed for several purposes. Their primary use is to support management of a non-normal condition. During the high workload conditions that often accompany management of a non-normal condition, the potential for selecting the wrong checklist is high. Accurate, rapid access to the appropriate non-normal checklist is required. In addition, pilots will want the ability to access individual checklists at any time for review.

Example(s)

Non-normal checklists are used on a need basis. A specific checklist could be accessed manually by means of the table of contents. Organizing checklists by the type of non-normal condition, as found in Quick Reference Handbooks, may be appropriate. Providing clearly visible checklist titles, together with a list of the indicators for the corresponding non-normal condition, can help crews to avoid selecting an incorrect checklist. This is particularly important for non-closed-loop systems.

In addition to manual access to individual checklists, closed-loop systems also support automatic access in response to system detection of a non-normal condition. An alert occurs and access to the appropriate checklist is provided when commanded by the crew.

Evaluation Questions

- Can each non-normal checklist be easily accessed?
- Is the appropriate non-normal checklist easily accessed when a non-normal condition is detected by a closed-loop ECL?

4.2.4 Open Checklists

Equipment Requirement(s)

> If the ECL supports more than one open checklist, the user must be able to access other checklists without having to close the currently displayed checklist first.
>
> Each checklist must have a constantly visible title to ensure that the user always knows which checklist is currently displayed.
>
> Note: An open checklist has been accessed by the user and is tracked by the ECL as "open." This open status means that if an open checklist is out of view, it can be accessed through quick operations that apply only to open checklists. For example, an ECL might provide a toggle button for moving only between open checklists or a master list that only includes open checklists. A closed checklist no longer receives this special tracking and cannot be accessed through operations that apply only to checklists having the open status.

Problem Statement

To manage some flight conditions effectively, the crew may want to access more than one checklist at a time. Flexible use of multiple checklists requires that the crew be able to move quickly between open checklists. Requiring the crew to close one checklist in order to open another checklist is inefficient and may discourage crews from fully utilizing checklists.

Example(s)

The crew is performing the 10,000 foot/climbing checklist. A left cowl anti-ice message appears on the EICAS. Because the cowl anti-ice is on, a low pressure condition is indicated. The climb checklist is not complete but they need to open the cowl anti-ice checklist because they are in icing conditions. They perform the first part of the checklist which ends with the command to leave icing conditions. After reconfiguring the aircraft to depart the icing conditions, they return to the climb checklist. Then they return to the cowl anti-ice checklist which, on the EFB, includes a natural transition to the ice dispersal procedure. Both of the open checklists are titled so that the crew knows which one is in view at any time.

Evaluation Questions

- Can the user easily transition to other open checklists without closing the current checklist?
- Does each checklist have a constantly visible title?

4.2.5 Multiple Open Checklists

Equipment Requirement(s)

> If more than one unrelated checklist can be open, the user must be able to choose which checklist is currently active.
>
> Note: The active checklist is the one which is currently displayed and the status of its items change in response to user actions.
>
> If one checklist is a “child” of another checklist in which it is embedded, the user must be able to choose whether the parent or the child checklist is active.
>
> Note: If one checklist is embedded in another, the higher-level checklist is called the “parent,” and the embedded (lower-level) checklist is called the “child.”

Equipment Recommendation(s)

> In place of parent-child checklists, create a single checklist that incorporates both.

Problem Statement

If multiple checklists can be open at the same time, the user must be able to choose which one is he/she is actively working on so that he/she can prioritize the order in which the checklists will be performed or so that he/she can review other checklists without closing the checklist in progress. If the user can not select which checklist is active, then the last checklist that was opened will be the default checklist in progress, but it may not be the highest priority one.

Examples

The user should be able to move between unrelated checklists, as well as related checklists. For example, a checklist with an embedded child checklist must allow the user to access child checklist. Once the child checklist is active, there must be a way for the user to return to the parent checklist.

Evaluation Questions

- Can the user move from one open checklist to another easily?
- Can the user move from a parent checklist to a child checklist easily?

4.2.6 Managing Multiple Checklists

Equipment Recommendation(s)

If more than one checklist can be open at one time, a master list of all open checklists should be provided.

Equipment Suggestion(s)

Access to an open checklist can be provided through the master list.

Problem Statement

Keeping track of multiple open checklists can be challenging when other tasks compete for the crew's attention. By providing a list of all open checklists, it is easier for the crew to be aware of pending checklist tasks.

Examples

A master list of all open checklists should be provided that is easily accessed at all times. This checklist queue can also be used to cycle through all open checklists.

Evaluation Questions

- Are open checklists all listed in one place?

4.2.7 Managing Multiple Non-Normal Conditions

Equipment Requirement(s)

> For closed-loop systems, all checklists required to manage multiple non-normal conditions must be listed together in one master list.

Equipment Recommendation(s)

> The master list of checklists to be completed for managing a non-normal condition should indicate the status of each checklist (e.g., pending, or completed).

Equipment Suggestion(s)

> Access to a specific checklist during a non-normal condition can be supported from the master list of required checklists for that condition.

Problem Statement

Multiple non-normal conditions may require the use of more than one checklist. Keeping track of which checklists need to be performed and the status of each checklist places additional demands on a crew that may already be overloaded. A closed-loop ECL can help the crew manage the performance of all required checklists while providing crews the flexibility to schedule checklist performance in accordance with other high-priority tasks.

Examples

A list of all checklists that must be completed for multiple malfunctions must be provided. The status of each checklist could be indicated within the master list. For systems such as the EICAS, the warning messages can indicate whether corresponding checklists exist. The indicator can also change color or otherwise reflect the status of its checklist.

In addition, this master list could provide direct access to the associated checklist. Doing so minimizes the potential for selection of the wrong checklist. A checklist button could be used to cycle through all checklists that must be completed, including those which were open when the non-normal conditions occurred.

Evaluation Questions

- Does the ECL indicate the checklists that must be performed when multiple malfunctions have occurred?
- Can the user easily access these checklists?

4.2.8 Putting Away the Checklist

Equipment Recommendation(s)

The ECL should allow a state where there are no currently open checklists.

Problem Statement

Checklists are not in use for a large proportion of a routine flight. With paper checklists, the crew simply puts the checklist back into storage. The act of storing a paper checklist indicates that the checklist has been completed and removes the checklist as a distraction. An equivalent capability should be supported by any ECL. Although an ECL may keep track of the next checklist to be used, it should not automatically open that checklist upon completion of the previous checklist.

Example(s)

After completing the take-off checklist and passing beyond 18000 feet in US airspace, there are no checklists to use under routine conditions. The checklists are stowed. On an ECL, a blank screen would indicate that there are no currently open checklists, as would a text message to that effect.

Evaluation Questions

- Does the ECL allow a state where there are no currently open checklists?

4.3 Checklist Actions

4.3.1 Indicating the Active Checklist Item

Equipment Requirement(s)

> The ECL must provide a pointer that indicates the active item in the checklist.
>
> Should this be a requirement or recommendation? Having an active item displayed can reduce possible errors with the checklist. However, some low-end systems do not have this capability. (Maybe it's a requirement for 121/135, but not 91?)
>
> If more than one unrelated checklist can be open or if the EFB supports multiple functions that can interrupt checklist completion, a placeholder capability is required to remind the user which item was active prior to leaving the checklist.

Problem Statement

A number of accidents and incidents have occurred, at least in part, because of the failure of the crew to complete all of the items in a checklist. Distraction, high workload, and other factors may cause the crew to unintentionally skip an item. Similarly, moving between checklists or other EFB functionality can result in the user losing his/her place in the checklist. Even with systems that indicate individual item status, additional time is required to identify the first uncompleted item in the list.

Example(s)

A pointer or box that surrounds an item can be used to indicate the active item. When returning to a checklist that was started but not completed, the item that was active prior to the move should again be active.

Evaluation Questions

- Is the active item clearly indicated?
- Does the ECL indicate the item in the checklist where the user was prior to leaving the checklist?

4.3.2 Moving Between Items Within a Checklist

Equipment Requirement(s)

Moving the active-item pointer to the next checklist item must require only a simple action by the user.

Again, this assumes an active-item pointer, which is not currently available on all systems, but is helpful in reducing checklist errors.

For ECLs that track the status of individual checklist items, the user must be able to move backward through checklist items to return to a previous item without changing the status of any of the items.

Equipment Recommendation(s)

For ECLs that track the status of individual checklist items, the user should be able to:

- Move from an uncompleted checklist item to the next item in the checklist, changing the status of the uncompleted item to "deferred."
- Move to the next item in the checklist automatically after a completing an item.

Equipment Issue(s)

Designers should consider how quickly the user is allowed to move to another item. If extremely rapid entries are accepted (e.g., holding down a key causes items to be checked off as fast as the key input stream can be read) the user may unintentionally skip beyond the desired item. If the user must stay on each item for a small period of time, the chances of moving beyond the desired item are reduced, but this solution may increase the overall amount of time required to perform the checklist.

Problem Statement

EFB users need to be able to move easily and quickly between items in a checklist. Some users are used to very rapid checklist accomplishment in the paper world and do not tolerate slower response from electronic checklists. Also, if users are not allowed to move around the checklists flexibly, they may take more time to complete the checklist, or they may become so frustrated with the ECL that they do not use it properly.

Example(s)

ECLs that use an active-item pointer must support easy movement to the next item in the checklist. This movement must require only a simple user action. For ECLs that track the status of individual checklist items, moving between items must not affect their status, except in the case of moving to the next checklist item from an uncompleted item. In this case, the status of the prior item should change from uncompleted to deferred.

In addition, the ability to move backward must be implemented to avoid forcing the user to move forward through all checklist items in order to return to the desired item. Backward movement alone must not change a checklist item's status.

Evaluation Questions

- Is it easy to move the active-item pointer to the next checklist item?
- Can the user move backward to a previous checklist item without affecting the status of any item? If the user moves forward in the checklist, are deferred items marked appropriately?
- Does the active item change to the next one in the list after an item is completed? Is there a tendency to skip items when attempting to move to the next item?

4.3.3 Specifying Completion of Item

Equipment Requirement(s)

> If the ECL requires a user action to indicate item completion, this action must be simple and distinct from the action of moving to the next item.

Equipment Recommendation(s)

> If the ECL requires an action to indicate item completion, the act of marking an item as complete should cause the next item in the checklist to automatically become active, except if the item is on the next page. A separate action should be required to move to the next page.
>
> Should an item have been incorrectly designated "complete," an easy undo should be available.

Problem Statement

An important advantage of electronic checklists is their ability to indicate which items within a checklist have been completed. This feature reduces the likelihood that an item will not be completed. An action separate from that of moving to the next item in the checklist should be required to change an item's status to "completed."

Example(s)

The user could press a button to indicate completion of an item. This button should be different from another button that might be used to move to the next item in the checklist without first completing the item (i.e., the other button would mark the task as "deferred" instead of completed).

Evaluation Questions

- Is the completion status of each checklist item indicated clearly?
- Does the action required to change an item's status differ from the action required to move to the next item if the item is not completed?
- When the status of an item has been changed to indicate completed, does the next checklist item automatically become active?
- Is a separate action required to move to the next page after all the items on the current page are completed or deferred?

4.3.4 Closing a Checklist

Equipment Requirement(s)

> If the ECL keeps track of item status and the user attempts to close an incomplete checklist, an indication that the checklist has not been completed must be provided.
>
> The user must be allowed to close an incomplete checklist after the indication has been acknowledged.

Problem Statement

One way to remind users to complete a checklist is to keep the checklist open until it has been completed. Once the checklist has been closed, the user may not remember to open it again and complete it without a reminder. There may, however, be circumstances where the user can reasonably want to close an incomplete checklist. Therefore, the user must always have the ability to close an incomplete checklist.

Example(s)

If the user attempts to close a checklist that has not been completed, a warning message could appear that reminds the user that the checklist has not been finished. The user would then be given the option to either go ahead and finish the checklist or to close it without completion.

Evaluation Questions

- Are incomplete checklists adequately marked as such?
- Is the user still allowed to close an incomplete checklist after acknowledging that it is not complete?

4.3.5 Undoing An Item Status Change

Equipment Requirement(s)

> If the ECL requires a user action to indicate item completion and the active item has been marked “complete,” changing its status either to a different status or to return it to the uncompleted status must be simple to accomplish.

Problem Statement

Pilots may make errors while completing a checklist. The ECL must support error recovery by enabling easy modification of an item whose status has been incorrectly modified.

Example(s)

Changing the status of an item could be implemented by selecting the item to be modified and then selecting the “return to uncompleted status” button. After the item is back in the uncompleted state, the user may change its status again if necessary to get to a different state, e.g., deferred.

Evaluation Questions

- Is it easy to change the status of an item to a different status, including uncompleted?

4.3.6 Displaying Item Status

Equipment Requirement(s)

> If the ECL indicates the status of an item (active, deferred, overridden, uncompleted, closed-loop sensed), a clear visual indication of that status must be provided.

Problem Statement

Users can be aided by having the ECL indicate the status of each item on a checklist. In addition to being either active or inactive, a checklist item can also be uncompleted, deferred, or overridden. A deferred item is one that the crew has skipped but intends to complete at a later time. An overridden item is one that the crew does not intend to complete. Finally, for checklist items presented by a closed-loop system, a checklist item can be either sensed or not sensed. A sensed item means that the ECL is able to detect when the crew has correctly completed the item.

Example(s)

Each checklist item state that is supported by the ECL must have a unique visual code that can be quickly discriminated under a range of lighting conditions. The code that is used should be consistent with other color code applications in the flight deck. Deferred items can also be moved to the end of the checklist to indicate that they remain incomplete.

Evaluation Questions

- How are the possible checklist states indicated and are they easy to recognize?
- Are the visual codes sufficiently unique as to be clearly discriminable under all likely lighting conditions?

4.3.7 Returning to Deferred Items

Equipment Requirement(s)

> If the ECL keeps track of item status, then before a checklist can be declared complete, the user must be required to return to deferred checklist items and complete or override them.

Problem Statement

One of the advantages of an EFB is its ability to remind users to complete all items on a checklist. Items might be deferred unintentionally, due to distraction, intentionally, for workload management or because the conditions are not right to complete the item, or because an unexpected event requires a transition to a non-normal checklist. If these items were not addressed at some point, the checklist would not be complete. To ensure that the checklist is completed, an ECL that keeps track of item status must remind the user to complete or override deferred items.

Example(s)

Reminders could be implemented at two levels. First, there could be visual indicators within the body of the checklist that indicate the presence of deferred items. The item itself could be color coded as a deferred item or the item could be moved to the end of the checklist. In addition, the checklist itself could have a visual indicator showing that it has deferred items. Also, a code could be used in a master list of open checklist that reflects the presence of deferred items in an open checklist.

Evaluation Questions

- Does a master list indicate the presence of one or more deferred items in an open checklist?
- Can a checklist be closed if it contains one or more deferred items?

4.3.8 Integrating Non-Normal Items into Subsequent Checklists

Equipment Recommendation(s)

Non-normal checklist items that are to be performed at a later time should be automatically integrated into subsequent checklists.

Problem Statement

Non-normal checklists can contain items that must be performed during subsequent phases of flight, in particular, approach and landing. Because they are to be performed at a later time, busy crews may forget to perform them at the appropriate time. Integrating these items into subsequent checklists can ensure that the tasks are performed at the correct time.

Example(s)

Instead of keeping incomplete checklists open, the ECL can move these items to a later checklist, allowing them to be performed at the appropriate time. An indication should be provided that these items originally came from a different checklist.

Evaluation Questions

- Does the ECL incorporate non-normal items into the appropriate checklists?

4.3.9 Lengthy Checklists

Equipment Requirement(s)

> A multi-screen checklist is one that has more items than can be displayed at one time on the EFB display. The ECL must allow the user to look ahead in a multi-screen checklist without changing the active item.
>
> If the user makes a change to an active item that is out of view, that active item must be brought into view.

Equipment Recommendation(s)

> While a multi-screen checklist is in use, the following information should constantly be available:
>
> - How long the whole checklist is
> - How far down the checklist the currently displayed information is
> - How much of the checklist has been completed.

Problem Statement

Some checklists are lengthy. With a paper checklist, the pilot can look ahead to see how long the list is, and judge how far along he/she is down the list. On an electronic display, the checklist may contain more items than fit on one screen at a time, even if the screen is relatively large. For task scheduling and other purposes, it is important to know how long the checklist is and how much remains to be completed.

While working on a lengthy checklist, the user must keep track of the current active item at all times. With a paper checklist, this can be done mentally, or with a physical reminder such as finger placement. With an ECL, the active item is tracked by the system, and must be displayed when a change is made to that item.

Example(s)

If the checklist is implemented in terms of discrete "pages," where each page represents the number of items that can be displayed at one time, then the current page and the total number of pages can be indicated using a convention such as "1/3," where the first number is the current page, and the last number is the total number of pages.

If the checklist is implemented on a scrolling window, a side scroll bar can convey all the required information. For example, if half the checklist has been accomplished, the graphical box or bar would be positioned midway down the vertical length of the window.

If the user moves ahead to view later pages or scrolls to a location where the active item is out of view, the active item must not change. If the active item is out of view and the user attempts to change the status of the item, the action must bring the active item into view.

Evaluation Questions

- When viewing looking ahead in a multi-screen checklist, does the active item remain unchanged?
- Is the active item brought into view when it is out of view and the user makes a change to it?

4.3.10 Confirming Completion of Checklist

Equipment Recommendation(s)

The user should receive a positive indication that the checklist as a whole, as well as each item in that checklist, is complete.

Problem Statement

A number of accidents have occurred because of the failure of the flight crew to complete all items on a checklist. Many paper checklists even include “checklist complete” as their last item, to ensure that the checklist is complete. Ensuring that a checklist has been completed is an important function that an ECL should support as well. This includes indicating both the status of the checklist as a whole and each item on the checklist. If a checklist-level indicator is not provided, the crew must take the time to scan each item in the checklist. If an individual-item indicator is not provided, the crew cannot determine which items are incomplete if no “checklist complete” message occurs.

Example(s)

Checklist completion could be indicated in two ways:

- Visual indications that show all individual items are completed
- Visual indication that the checklist as a whole has been completed

Both completion indicators should be provided. An aural indicator may also be used.

Evaluation Questions

- Is the completion of all individual items indicated?
- Is the completion of the entire checklist indicated?
- If provided, is the aural indicator of checklist completion clear ?

4.4 Options

4.4.1 Links Between Checklist Items and Related Information

Equipment Recommendation(s)

> A set of links to information related to individual checklist items should be provided when that information is also part of the EFB. The links could direct users to additional information about that item, about the system addressed by the item, and/or to MEL information for that system.
>
> Returning to the checklist item from the related information should be a single-step action.
>
> In addition, the related information should appear in a single window or area of the screen. If hyperlinks within the related information are activated, the information in that one window (or area) should be updated, rather than opening a separate window with the new content.

Equipment Issue(s)

> In choosing the type of information that is linked to a particular checklist item, designers should consider what type of information is most likely to be needed by the crew. This information should be easy to access. If the user is allowed to select the type of information to access, there should be a consistent method for making this selection.

Problem Statement

Even though crews are highly trained and practiced on the use of checklists, they may occasionally find that they need to look up related information. The ECL can make it much easier to find related information. This feature will increase usability as well as user acceptance of ECLs.

The related information could be about that item, the system addressed by the item, and/or the MEL information for that system. Additional information about a particular item may be especially useful for less experienced users. Links to related information about a particular system could be useful particularly as a study and review tool. Links to MEL information would provide immediate access to the implications of a non-normal condition identified through checklist performance.

The related information should appear in one place (window or area of the screen) on the EFB. If the user is allowed to follow a chain of hyperlinks, it is important that he/she does not become confused as to how to return to the checklist, or to a previously selected link. A standard way of guarding against this type of confusion is to allow only one window to show related information. When a chain of links is followed, the user has the option of returning to the previous link or selecting a new link; either of these actions would replace the content that is currently displayed.

Example(s)

A direct link to related information could be implemented by means of a hyperlink initiated from the checklist item. Another way to access related information would be through a pop-up menu that appears over the item when called up. The user could choose the information they wanted to view from this menu.

In either case, returning to the original checklist item should be a single-step action. For example, if a "help screen" is open, there could be a button on it labeled "Return to Checklist". There might also be other links on the help screen, pointing to other related information. If those hyperlinks are selected, no other windows should open; instead, the contents of the help screen should be updated.

Evaluation Questions

- Does the ECL provide links to useful, related information? Is it easy to select what information to view?

- Can the user return to the checklist from related information in one step?
- Is the related information always shown in one window or area of the screen regardless of how many links were selected?

4.4.2 Links to Special Information for Ongoing Non-Normal Conditions

Equipment Suggestion(s)

Users should easily be able to access procedural, system, and operational notes and other information pertaining to any ongoing non-normal condition.

Problem Statement

Procedural changes are often made in response to a non-normal condition. In addition, some non-normal conditions can result in the loss of other systems. For example, in some aircraft, a hydraulic system 1 failure also causes the loss of the outboard ground spoilers. It can be challenging to remember this information because it may apply to subsequent phases of flight, and because crews are very busy in these situations, particularly when multiple non-normal conditions have occurred.

In order to relieve pilot workload and minimize the opportunity for error, ECLs could provide easy access to all procedural and operational notes and other appropriate information pertaining to an ongoing non-normal condition. This information could then be reviewed at the appropriate time, enabling the crew to prepare for each flight phase in advance. Customization of the information may be useful as well.

Example(s)

Ongoing non-normal conditions, inoperative systems, procedural changes, operational limitations, and other information could be listed in one area. Advanced versions of this function could allow the user to select which checklists to pull this information from or to choose specific paragraphs from operating manuals and other documents for inclusion.

Evaluation Questions

- Can the user access checklist information for non-normal conditions easily at any time?
- Can the user customize the information for a non-normal condition?

4.4.3 Links to Calculated Values

Equipment Requirement(s)

> If the EFB provides calculation worksheets, easy access from the checklist item to the corresponding worksheet must be provided to support initial calculation, as well as subsequent review and modification of the calculated value.
>
> ECL values that were calculated in a linked worksheet must appear in the corresponding checklist location. The corresponding checklist fields must be blank prior to insertion of the calculated value.

Training/Procedure Requirement(s)

> Procedures must be in place that define the roles the flight crew and dispatch play in creating and reviewing performance calculations supported by the ECL.

Problem Statement

Some checklist items involve setting a system value that has been calculated from one or more tables. The calculation worksheet may be immediately accessible from the corresponding checklist item. If the EFB supports performance calculations, the calculated value must appear in all appropriate checklist locations.

Example(s)

Direct access to the appropriate worksheet must be provided for all checklist items that can be calculated using the EFB. In addition, the user must be able to easily return to the checklist item from which the worksheet was accessed, even if the calculation was not attempted or completed.

Any checklist field that requires a calculation must be empty until the calculation has been completed. Once complete, the value must appear in all appropriate checklist locations. Access to the calculation worksheet must be supported even after the calculation has been completed to enable the user to review the assumptions on which the calculation is based.

In addition, the checklist item and the corresponding calculation worksheet should support access to background information that is useful to understand the calculation.

Evaluation Questions

- If the EFB provides worksheets, how are the appropriate worksheets accessed from the checklist items that require them, and is this easy to accomplish?
- If the EFB provides worksheets, how does the user return to the checklist item from the worksheet and is this easy to perform?
- If the EFB supports worksheets that are linked to specific checklist locations, is the checklist item
  - Empty prior to the performance of the calculation?
  - Filled in after the performance of the calculation?
- How is access to the worksheet supported if the user chooses to return to the calculation after it has been completed and is this easy to accomplish?
- Does the ECL provide background information that can help the user understand how to perform the calculation?
- Does the air carrier have procedures in place that define flight crew and dispatch roles in creating and reviewing performance calculations supported by the ECL?

4.4.4 Task Reminders

Equipment Recommendation(s)

> ECLs should provide reminders for tasks that require a delayed action to ensure that the task is completed at the appropriate time.

Equipment Requirement(s)

> If the ECL supports task reminders, the reminder must be displayed constantly once in progress, and it must attract the pilot's attention at the time that the delayed action should be performed.
>
> If multiple task reminders can be in progress at one time, crews must be able to determine how many are in progress and to what tasks they refer.

Problem Statement

Pilots may become distracted and forget to complete tasks that require a delayed action (e.g., *stopping* a fuel transfer). ECLs that provide a reminder to complete the delayed action can ensure that the task is completed at the correct time.

Example(s)

An example of a task that requires time to complete is a fuel transfer. After the fuel transfer is initiated, the crew typically completes other tasks while the transfer progresses, since the transfer may last several minutes. After the correct amount of time has passed, the crew must stop the fuel transfer, but by this time they may be engaged in other tasks. An ECL reminder that attracts their attention at the correct time could ensure that the fuel transfer does not go on too long.

The reminder could be a visual icon in one corner of the display. It could begin to flash to attract attention. An aural warning could also draw the crew's attention to the visual indicator.

Multiple task reminders could be indicated in several ways. One approach is to use an icon with a number on it that indicates the number of active reminders. The user could click on the icon to access a master list of all active reminders together with pertinent information such as expiration time. Another approach is to use one icon for each reminder. Clicking on the reminder would access more information about that task.

Evaluation Questions

- Does the EFB provide reminders for tasks that require a delayed action?
- If task reminders are provided, how are multiple reminders indicated and is it easy to determine what tasks they are associated with?
- Can the user easily review what a reminder is for?

4.4.5 Checklist Branching

Equipment Requirement(s)

> When a checklist branches based on a key decision, the selected branch must be clearly indicated.
>
> The user must be able to backup to the decision step and choose another decision branch to allow recovery from an erroneous choice.

Equipment Recommendation(s)

> Items that are not on the selected branch should not be selectable.

Problem Statement

While performing a complex checklist, the pilot may have to make key decisions at several points, and choose a branch of that checklist based on each key decision. Keeping track of the active items along a given branch mentally can be cumbersome and error prone.

ECLs that clearly highlight the selected branch of a checklist can ease the mental burden of keeping track of which items to perform. Also, by clearly encoding the selected branch, the pilot may be more aware of the decision he/she made to select that branch. If items that are not along the selected branch are deactivated, then the pilot cannot mistakenly perform them.

Example(s)

Decision branching can be indicated by means of a yes/no indicator or graphical means of depicting the alternative choices and checklist branches in response to an explicit, clearly written question. Double negatives should not be used in the question. Based on the user's choice, the user is taken to the next set of items required for that situation. The user must be allowed to change his/her choice by backing up to the decision step in the checklist.

Items that are not along the selected branch could be encoded by a text color, such as a dim gray, or they could be hidden. If they are hidden, the user should be able to view these items for review on request.

Evaluation Questions

- Are decision branches clearly indicated within a checklist?
- Are the checklist questions written clearly?
- Can the user recover from choosing the wrong branch easily?

4.4.6 Modifications to ECLs used for Part 121/135 Operations

Note: How to address Part 91 customization?

Equipment and Training/Procedures Recommendation(s)

> Paper checklists are often customized by individual operators. Similarly, ECLs should be easily modifiable by airline personnel, rather than requiring modification by the manufacturer, so that paper deviations and supplements are not required.
>
> The air carrier should develop procedures and tools to modify checklists that minimize the opportunity for error. These procedures and tools may be subject to regulatory review and approval in order to ensure that modifications are made accurately, particularly if the ECL supports closed-loop items (i.e., checklists items that are sensed directly). The modification process should also ensure that conflicting versions of the ECL are not in use.
>
> What parts of the checklist should be customizable? Boeing does not allow user-interface customization of ECL, but others might. All Boeing mods are made on the ground.
>
> Doe mods of closed-loop ECL require formal review?
>
> Should there be a formal validation of the ECL after modification?

Problem Statement

Many customers will request ECLs and support tools (e.g., ground-based software) to customize the content of a checklist in-house. It will be more efficient for airlines to make changes directly as compared with having the ECL manufacturer involved every time an update is necessary.

In particular, it is important that urgent or significant changes to ECLs are made efficiently, in order to avoid use of paper supplements. Paper supplements could cause confusion and errors, particularly high workload non-normal conditions.

Example(s)

Ground-based tools could include automatic documentation of changes, to build an audit trail. The audit trail could be used by company and FAA personnel to verify and review changes. The audit trail could record which ECLs were changed (e.g., which fleet was affected) and why. It could also verify that all necessary related changes were made.

If changes to the ECL cannot be made in a timely fashion and a paper supplement is required, the air carrier should consider whether to issue a paper supplement with appropriate notification to flight crews or whether to temporarily return to use of paper checklists instead of the ECL.

Note: need to include some examples of what should be user customizable, and what shouldn't.

Evaluation Questions

Note: Need to fill in some questions.

- Does the ECL allow the airline to easily modify checklists?
- What precautions are in place to avoid errors during changes to ECL?
- Is their an audit trail to track changes?

5 Flight Performance Calculations

5.1.1 Aircraft Performance Documentation

Training/Procedures Requirement

> Procedures must be developed to ensure that any information required to be available outside of the aircraft is transferred from the EFB at the appropriate time and place.

Equipment Suggestion

> Even if there is no legal requirement to be able to transfer data off of the EFB, the ability to do so is desirable.

Problem Statement

EFBs may be used to compute flight performance data. In some cases (e.g., Part 121 Operations), copies of this computed information are required to be deposited at a ground station prior to takeoff. Therefore, there must be a procedure for transferring the data from the EFB to some other media (e.g., paper), or onto a different ground computer.

Part 91 operators may not be legally required to transfer data off the EFB, but would benefit from the ability to do so.

Example(s)

Weight and balance data must be available in either paper or electronic format to airline personnel other than the crew. One way of handling this requirement is to send the information electronically from the EFB to company flight dispatchers. An alternative would be for the EFB to print out the required information onto paper, which would then be left at the point of departure.

Evaluation Question(s)

- What is the procedure for ensuring that, if necessary, EFB data can be stored outside of the device?

5.1.2 Data-entry Screening and Error Messages

Equipment Recommendation(s)

> If user-entered data is not of the correct format or type needed by the application, the EFB must not accept the data. An error message should be provided that communicates which entry is suspect and specify what type of data is expected.
>
> When an incorrect item is identified, only that item should be discarded, not the whole set of entries related to the particular task in progress.

Problem Statement

While pilots who use an EFB may receive some training in use of the device, designers of the system should not expect users to be experts. Well designed error messages help to reduce the training time, promote acceptance of the device, and aid in recovery from errors. Not all entry errors can be caught with data screening, but such screening can be quite effective nonetheless. In order to limit the amount of data that must be re-entered after an erroneous entry is discovered, only that entry should be discarded, not the whole set of entries related to the particular task in progress.

Example(s)

In entering flap settings for a takeoff performance worksheet, values outside the normal range of flap settings (e.g., a three digit, or alphabetic entry) should not be accepted. If an invalid entry is made, the error message could state that a number between 0 and 30 (or whatever the maximum flap setting is for that aircraft) is required.

Evaluation Question(s)

- Are errors in data entry identified clearly to the user?
- Does the error message clarify the type and range of data expected?

5.1.3 Support Information for Performance Data Entry

Equipment Requirement(s)

The units of each variable used in the software must be clearly labeled.

Equipment Recommendation(s)

> The labels, formats, and units of variables used in the software should match the labels, formats, and units of the data available to the user from other sources of information (e.g., paper reports).
>
> In performing a task, if the user may need to cross-check with other computations or data stored within the application, the related information should be in view, or else easily accessible.

Equipment Suggestion(s)

> Definitions of specific terms used in the software should also be easily accessible (e.g., via hyperlinks, or pop-up information areas.)

Equipment Issue

> When data entry is required, the EFB designer should consider whether that data will be readily available to the user. If the data are not generally known or easily accessible, the logic of the task may need to be rethought.

Problem Statement

The user should not have to manipulate what information is in view in order to complete a single logical task. All the information necessary to complete that task should be in view, or else easily accessible. If some necessary information is out of view, the user may make errors, or may not catch errors made previously. If the necessary information is difficult to access, the speed and accuracy of task performance will suffer, and increase pilot workload. This section might be easier to parse if the topics are described in the same order they're introduced in the requirements and recommendations statements.

System designers should consider whether the data requested will be readily available to the user, and whether the format available to the user matches the format expected by the software. If the data are not generally known or easily accessible, the logic of the task may need to be rethought. Other support information includes the definition of terms (e.g., what is a "damp" runway?), and unit labels.

Example(s)

In computing various flight performance data, the user may need to refer to route information, which should be in view or readily accessible.

Different airline operators may use different terminology to refer to variables used in various computations, such as weight and balance. The terminology used in the software should match that used by the airline in any other paperwork (e.g., maintenance, dispatch release forms, or fuel records).

Evaluation Question(s)

- Is all the information necessary for a given task presented together, or at least easily accessible while performing that task?
- Does the terminology used in the software match the terminology used in other operator documents?
- Are units clearly labeled?

5.1.4 When and How to Do Performance Calculations

Training/Procedures Recommendation(s)

In order to reduce the possibility of errors, users should learn to complete performance calculations at particular times within the flight. They should also plan to complete the calculations in a certain order, and through a certain set of ordered steps.

Training/Procedures and Equipment Recommendation(s)

In designing the flow of steps for completing a task in the software, designers should consider whether that flow is logical to the user and can be trained easily. Similarly, training on how to do a performance calculation should be matched with the steps in the software.

Equipment Suggestion(s)

The software could prompt or remind the user of the order of steps for completing a task.

Problem Statement

Performance calculations are usually completed in a series of steps. In some cases, the steps must be completed in a particular order, but in other cases, the order of steps is not critical. When the order of steps is important, the software should prompt the user for information in that order. Even if the order of steps is not critical, users should be trained on the process for completing the task so that they are less likely to forget individual steps.

Users should also be trained on when to initiate and complete performance calculations with respect to the flight timeline.

The software should be designed to match the users expectations with regard to the order of steps in the process, and the training should be designed to reinforce this procedure for completing a calculation.

Example(s)

Weight and balance computations are usually done at the gate while passengers are boarding. However, the weight and balance data may change significantly at the last minute, and so should be easily modifiable just prior to takeoff.

Evaluation Question(s)

- Are users trained on when and how to do performance calculations?

5.1.5 Default Values

Equipment Recommendation(s)

In general, default values should be based on the most conservative parameters for that calculation.

Equipment Issue(s)

EFBs that are connected with other flight deck systems may be able to acquire default values from these systems. If however, the communication with the other system is lost, designers must have a backup plan for assigning default values.

Equipment Suggestion(s)

The software could highlight default values in order to remind users to review those values carefully.

Problem Statement

Default values can be useful in speeding a routine calculation task. However, default values should be selected carefully because they may not always be carefully reviewed by users. Incorrectly assigned values could result in significant miscalculations. One way to mitigate the potential negative effects of default values is to always select the most conservative values for that situation.

Example(s)

In computing landing performance, the default value for runway conditions could be the one requiring the longest runway length.

Evaluation Question(s)

- Are the default values conservative?
- Are any defaults obtained from other flight deck systems? If yes, what is the backup plan for assigning these values if communication with the other system is lost?

5.1.6 Coordination Between Flight Crews and Ground Dispatch Personnel

Training/Procedures Recommendation(s)

> Procedures should be in place to define and coordinate any new roles the flight crew and dispatch may have in creating, reviewing and using performance calculations supported by EFBs.

Problem Statement

In many airline operations today, ground dispatch personnel are responsible for completing flight performance calculations. The flight crew reviews and approves the flight plan that the ground dispatcher has prepared. These roles may be altered by the introduction of an EFB application that allows flight crews to perform the calculations. In order to prevent any confusion about who is responsible for completing the calculations, or reviewing them, the new roles of the flight crew and dispatcher should be coordinated. Both the flight crew and dispatcher should be working from a common set of data, and they should both have a common flight plan prior to the flight.

Example(s)

The flight crew may be able to use an EFB to modify or check a flight plan quickly just prior to departure, taking into account any last minute changes to the weight of the aircraft, or any last minute changes in the departure runway (e.g., to check if they can take a shorter runway). If dispatch is not involved in checking these last minute changes, they may need to be informed by the crew at their earliest convenience as to the changes that occurred. The crew may inform dispatch via voice, or possibly through data link.

Evaluation Question(s)

- Are the roles of dispatchers and flight crews coordinated?

6 Electronic Charts

While some in the industry would like to see a quick changeover from paper charts to electronic charts, in this document we assume that there will be a significant transition period over the next few years where both paper and electronic charts co-exist on the flight deck. Overall, the guidance covers this transition period more so than it covers the end-state that many hope for, where sophisticated electronic charts are the norm.

To provide a framework and context for these considerations, background on aeronautical charts, both paper and electronic, is presented in Section 6.1 below. General human factors considerations for expected “first generation” electronic charts are presented in Section 6.2. More information on best practices for database-driven electronic charts can be found in the draft SAE ARP on Electronic Charts.

While guidance for approval of electronic charts is provided in this chapter, evaluators and designers should keep in mind that any aeronautical charts used in high workload situations, such as takeoff and landing operations, will require significant evaluation (see 2.1.4 Use of EFBs During High Workload Phases of Flight). Also, the guidance in this chapter applies only to terminal charts (specifically, approach plates, airport taxi diagrams, and arrival/departure procedures). The chapter does not address in detail issues such as enroute charts, integration of other information such as notices to airmen (NOTAMs), integration of dynamic traffic and weather information, or display of information tailored for a specific operator.

6.1 Background

6.1.1 Review of Paper Charts

Aeronautical charts are a rich source of information for conducting flight operations. They provide a variety of information that, in many cases, is required for flight (see FARs. 91.103 Preflight Action; 121.549 Flying Equipment; 125.215 Operating Information Required and 135.83 Operating Information Required). They are standard equipment in any pilot’s flight bag.

Pilots use aeronautical charts as both a planning tool and as a source of specific, detailed reference data (Wright and Barlow, 1995). As planning tools, charts help the pilot to envision the procedure to be flown by providing information such as which navigation aids will be used, and/or altitudes and headings to follow for a published approach and landing procedure. Charts also contain a great deal of reference data such as minimum parameters for landing under different weather and equipment conditions, terrain elevations, and radio frequencies.

Different types of charts are used in different stages of the flight and under different operating environments. Under visual flight regulations (VFR), color VFR sectional charts are used. Under instrument flight regulations (IFR), approach plates provide specific and detailed information for each published approach to a runway end. IFR enroute charts provide long range navigation information for IFR operations. These typically place less emphasis on visual navigation than VFR sectional charts and therefore provide less detailed terrain information. In IFR operations, pilots may also have to follow published arrival and departure procedures, which depict how the aircraft is expected to enter the traffic pattern at busy airports.

To date, charts are generally used in paper form. Paper aeronautical charts have evolved into their present size and configuration. They present a large amount of information in a relatively small space, using special symbols and drawing conventions. The symbols and drawing conventions sometimes vary between chart manufacturers, so pilots typically use charts from a single manufacturer for most, if not all, of their flights. While there are many similarities among charts produced by different manufacturers, there can be small, but significant, variations. Many nation states, including the United States government, publish charts in accordance with standards set by the International Civil Aviation Organization (ICAO). Independent chart providers, such as Jeppesen Inc., are not required to follow the ICAO standards, but generally do so.

From an operator's point of view, the main disadvantages of paper charts include (a) their weight and bulk, and (b) the time, manual effort, and resulting cost and potential for human error associated with keeping paper charts up to date. Paper charts often weigh several pounds by themselves, particularly if the aircraft is used for global operations. Updating paper charts is a tedious process and charts could easily be incorrectly updated.

6.1.2 Types of Electronic Charts

Different electronic chart applications are expected to evolve. Eventually, there will be a range of electronic chart applications that support different levels of functionality and interactivity. The simplest charts may be similar to electronic documents (see Chapter 3) in that they cannot be configured interactively. The next step up would be electronic charts that have limited interactive (non-paper-like) features, such as user control over what chart portions are displayed (as in the JeppView FliteDeck™ 1.0 product). In a limited-interactive electronic chart, portions of the display may be non-interactive like paper (such as the plan view depiction in JeppView FliteDeck™). Groups of elements would be stored as objects that can be manipulated, but not every symbol on the chart will be stored as an individual object.

Manufacturers are also working towards database-driven electronic charts, in which every element will be stored in a database. As a result, database-driven charts will support a great deal of user interactivity, as well as, potentially, interactivity based on knowledge of phase of flight and other data from a flight management system. Partially database driven electronic charts could support some de-cluttering capabilities (e.g., filtering out obstructions that are below your current altitude). Fully database driven charts could offer a great deal of flexibility in de-cluttering the display, including algorithms that could dynamically configure the display for the aircraft's specific position. For example, the application could remove all information for an arrival procedure that does not apply specifically to the arrival path in use.

As electronic charts become more advanced, it will be important to understand their overall impact in the flight deck. Specifically, integrated EFBs that have knowledge of aircraft variables (such as its position) and built in artificial intelligence logic need to be designed and evaluated in relation to the moving map displays that are available in many aircraft. The electronic chart application would likely have more detailed and up-to-date data than the navigation data base, so, if desired, it could notify the pilot of certain conditions, such as proximity to terrain or special use airspace, or even a mismatch between the approaches selected on the EFB and FMS. Another example of an advanced ("intelligent") EFB feature would be if the EFB were capable of selecting a chart, or an airport, in response to some kind of abnormal or emergency situation in flight. For example, if an aircraft experiences a hydraulic failure that limits flap deployment, the EFB could automatically search for a runway at the destination airport that could accommodate the higher landing speed and bring up the associated chart. However, the logic used for these functions would need to be designed and evaluated carefully.

Another potential benefit of electronic charts is that they need not be discrete documents any more, but instead may become part of a complete map that combines approach charts, en route charts, and so forth into a seamless whole. This may change the way pilots access needed information, and may enable them to look beyond the boundaries of a given discrete chart to see how it relates to other charts and features of the area.

Recently, there has been significant industry development of electronic charts for EFBs. A lightweight EFB could store and display charts while taking up less volume and weight than the equivalent set of paper charts. In addition, electronic charts are desirable because they can be updated electronically, and because they could support new, dynamic functionalities, such as real-time displays of own aircraft position along the route of flight if approved for use. Another advantage of electronic charts is that data on the chart could be customized, or even removed, for a given operation. The customization could be performed in advance, on non-interactive charts, or it could be performed dynamically on integrated EFB with database driven charts.

6.1.3 Comparison of Paper and Electronic Charts

A major advantage of paper charts is the operational utility and usability has been established through years of in-flight use and evolution. In contrast, there is little operational experience with electronic charts in non-military aviation. In particular, there is a need for more data collection and analysis of how often different chart data and chart types are used in order to design good user interfaces for electronic charts (see 2.4.1 User Interface Design-General). For example, what order are charts usually used in? What information is "most important" and when? How do usage patterns vary based on type of operation (e.g., Pt 91 versus Pt 121/135 operations, use of charts at familiar versus unfamiliar airports, or even use of charts during short-haul versus long-haul flights).

Paper and electronic charts are compared and contrasted along several dimensions in Table 6-2 and Table 6-2. Notice that several issues for electronic charts are raised. These issues are discussed later as well, in the associated considerations.

Updating	Paper Charts	Manual updates. Prone to human error. Time-consuming
	Electronic Charts	Integrity of data should be checked prior to distribution. Automated updates. Prone to automation errors. Quick. (See 2.4.15, 2.4.16, and 2.4.17 for related guidance.)
Clutter	Paper Charts	Clutter is unavoidable because several procedures are commonly incorporated on one plate to minimize the volume of paper. In some cases, clutter can be controlled through good design and high level of customization for a specific audience, but not always. Complexity of content will affect how much information is displayed, indirectly affecting clutter. Users must search through data (e.g., landing minima) that may be irrelevant to their specific operation. Clutter cannot be controlled by user.
	Electronic Charts	Potentially less clutter because may be easier to customize for specific audiences (e.g., only show data applicable to a particular operation) automatically. User may have some control over clutter with a database-driven chart (e.g., select whether some elements are shown or not). However, there is additional workload associated with configuring the display to bring up desired information. Some of the workload of configuring the electronic chart could be offset by an intelligent chart system that correctly anticipated user needs for information. Charts that store information as a graphic, instead of in a database format, would not be able to support a flexible, user-controlled de-cluttering capability.
Legibility of Individual Symbols/ Characters	Paper Charts	Symbology on paper charts is designed for legibility at relatively close viewing distances (approximately 12-15 inches). Reference data is usually smaller in size than procedural information. Symbology also optimized for use on standard size chart (approximately 5 inches by 7 inches). The user can position the paper chart at a comfortable distance to optimize legibility.
	Electronic Charts	May be difficult to read small characters/symbols if they are transferred directly (i.e., the same size, stroke width, etc., are retained) from paper charts. Paper highlighting techniques (e.g., bolding) may not transfer well to lower resolution electronic displays. If the EFB cannot be repositioned physically, the smallest characters/symbols may need to be larger than they are on paper charts. The resolution of the electronic display and other characteristics of the display technology will affect symbol/character legibility (see 2.4.10 through 2.4.13, and 0). Characters/symbols could be modified for better legibility on electronic displays with significantly lower resolution than paper.
Use of Individual Charts	Paper Charts	User are highly familiar with paper charts (may be especially familiar with one particular manufacturer's charts).
	Electronic Charts	May require training to learn how to use individual charts, depending upon similarity to paper charts. New functions could be supported (e.g., integrate with real-time display of own aircraft position); these may also require some training.

Table 6-1 A comparison of paper and electronic chart features (continued on next page).

Accessing Charts	Paper Charts Familiar process for accessing individual charts. The process relies on the human knowing what chart is necessary. Charts expected to be used in a particular flight can be set aside in advance (e.g., destination arrival procedure). The time to bring up a desired chart can be lengthy because of the large number of paper charts that must be searched.
	Electronic Charts May require training to learn how to access a desired chart. Potentially quicker access (on the order of a few seconds), but poor implementations (e.g., lots of steps) could increase workload. Potentially new ways of accessing individual charts (e.g., custom searches for charts matching specific criteria). Also, if connected with FMS, could potentially assist in error checking by double-checking user's selection and asking for confirmation of selection if inconsistency is found.
Accessibility of Information	Paper Charts Both planning and reference information is available all in one place. No need to reconfigure the display to access any particular type of information. Information is constantly available; no need to "share" the display with other functions.
	Electronic Charts May require training on how to configure display and how to bring up desired reference data quickly May need to obscure the chart to access other EFB functions.

Table 6-2 A comparison of paper and electronic chart features (continued).

6.2 General

6.2.1 Logical and Visual Structure of Electronic and Paper Charts

Equipment Recommendation(s)

The logical structure of electronic charts should match that of paper charts, particularly if paper backups are still in use. That is, information that is grouped in paper charts should also be grouped in electronic charts.

The visual structure of electronic charts, including symbology and general layout, should be compatible with that of paper charts, although it is not necessary to copy the visual structure of paper charts exactly.

Equipment Issue(s)

Some visual elements of paper charts (e.g., methods of highlighting information, fine line widths, or font choices and sizes) may not transfer well to lower resolution electronic displays directly. Some modifications may be necessary to maintain legibility of the electronic chart.

Training/Procedures Issue(s)

Pilots may need training to learn how to configure and use individual electronic charts, depending upon their logical and visual similarity to paper charts. Any functions supported on electronic charts that are not available on paper charts may also require pilot training.

Equipment and Training/Procedures Issue(s)

If paper backup charts are not in use, the electronic chart may be modified significantly from the familiar format. Before the new chart format is adopted, the design should be studied thoroughly in terms of its usability. Issues such as training time, potential negative transfer from extensive familiarity with use of paper charts, and overall task performance should be considered and evaluated.

Problem Statement

Because pilots are highly familiar with the logical and visual structure of paper charts, electronic charts should be based on the same basic structure, at least during the transition stage from paper to electronic charts, particularly if paper backups are still in use. If the electronic chart is created based on a totally new structure, pilots may not be able to transfer their knowledge of paper charts and more training will be required. Also, confusion and errors are more likely if pilots do not find the electronic information where they expect it to be based on their experience with paper charts. In some cases, there may even be negative transfer from paper charts, meaning that habits that helped pilot to use paper charts actually hurt their performance with electronic charts if the formats are contradictory

Example(s)

Paper charts are divided into sections (e.g., plan view, profile view, minimums table, etc.). These sections should be available as units in electronic charts as well, although they may not be visually arranged in the same way as they are on a paper chart.

In order to be compatible with the visual structure of paper charts, which are usually oriented vertically (i.e., in portrait mode), electronic charts should also be presented in portrait mode.

A symbol on a paper chart may have more detail than the corresponding electronic symbol, but the basic shape should be recognizable across the two media.

Pilots are used to seeing paper charts in north-up orientation. If electronic charts are track up, their orientation must be clear so that pilots do not revert to their traditional expectations based on paper charts.

If the pilot is used to looking in one place for a particular bit of data (e.g., the top of the page) and

Evaluation Questions

- Do the electronic charts match paper charts in terms of their visual and logical structure?

6.2.2 Paper Corrections/Updates to Electronic Charts

Equipment Recommendation(s)

Corrections or updates to electronic charts should not be made via paper notifications to flight crews, especially if they contain high priority or time-sensitive data. Corrections and updates to electronic charts should be made to the electronic charts themselves, unless they are of a temporary nature.

Problem Statement

In order to rely on electronic charts, pilots must be sure that, as long as the database is current, the charts are accurate and up to date. Pilots should not have to remember to check for more recent paper corrections or updates to charts. Paper amendments to electronic charts could lead to confusion and errors, particularly in high workload non-normal conditions.

Example(s)

Changes in the final approach course or runway length may need to be updated on the charts. If the changes are permanent (at least relative to the update cycle of the charts), these changes should be made through an electronic update.

Evaluation Questions

- Are all corrections and updates to electronic charts made electronically? If not, how are updates handled?

6.2.3 Hard Copies of Electronic Charts

Equipment Requirement(s)

> If the electronic chart can be printed out from the EFB, hard (paper) copies must be legible. That is, the quality of the printer and paper should be such that all chart details are clearly visible.

Equipment Recommendation(s)

> If color is used on the electronic chart, then any hard copy chart generated from the EFB should also be in color. If printing is in monochrome, but the chart uses color, all the information should be preserved and visible (e.g., terrain coding).
>
> EFB generated hard copies should be printed at full size (i.e., the same size as a paper chart prepared by that manufacturer) or larger for best utility. Selection of a chart size, if more than one option is available, should be made by the user.

Problem Statement

In the absence of significant operational experience with electronic charts, paper copies of charts are likely to be required in the flight deck as backups to electronic charts, at least for some transition time. In some cases, the EFB may be able to print out charts on demand from its electronic data bases. If hard copies of charts are printed from an electronic database, they must be legible, or else they will not be satisfactory substitutes for the original manufacturer's paper charts. If chart details cannot be read, it will not be usable in flight; if chart details are difficult to read, pilot workload and head-down time will suffer.

In order to obtain satisfactory quality of printouts, the charts should be printed out at a size that is equal to or larger than its original paper equivalent. Charts that are printed at a reduced size are likely to be more difficult to read and use than current paper charts are.

Example(s)

It may not be necessary to store an entire set of backup paper charts in the flight deck. Instead, only charts that are expected to be used for that flight (e.g., for the origin, destination and alternate airports) could be printed out from an EFB onto a flight deck printer a short while before the flight. The output of the printer must be of sufficient quality that the chart can be used as effectively as an original paper chart.

If enroute charts are also available on the EFB, they could also be printed out for use as paper backups during the flight.

Evaluation Questions

- Are charts printed from an EFB as legible as their original paper counterparts?
- Are charts printed out at full size or larger? Can users select the output size?

6.2.4 Scale Information

Equipment Requirement(s)

> If depicted, chart scale information must be accurate. If accurate scale information is not available, a scale must not be displayed.

Equipment Recommendation(s)

> An accurate chart scale should be visible, especially if the display can be zoomed.

Problem Statement

Paper charts usually show scale information, such as 1 inch represents 5 nautical miles. If zooming is implemented, however, an inch may represent some distance other than the standard shown in the scale. Because pilots must not be misled by inaccurate scale information, the chart scale must either be accurate, or deleted from the electronic chart.

When the display can be zoomed, a standard unit of measurement (such as “one inch”) will represent a different distance on the chart. In order to estimate distances, it is useful for the pilot to know what 1” actually does represent on that particular depiction.

Example(s)

A pilot may use a variable zoom in to view a detailed area of the chart to gather specific reference information, such as the frequency for a navigation aid. At this zoom level, which is not a standard preset, a physical distance of 1” on the screen may represent an unusual actual distance, such as 3.8 nautical miles. Instead of depicting the scale as 1” = 3.8 NM, one option is to show a line that is the length needed to represent a typical distance, such as 5 NM, and leave out the text description.

Evaluation Questions

- Is chart scale information accurate when depicted?
- Is accurate scale information depicted?

6.2.5 Basic Zooming and Panning

Equipment Recommendation(s)

> If the chart can be zoomed, its visual edges should be clearly marked. Visual edges should only be used when there is no further information outside that area so that the user knows that absence of an edge indicates the existence of off-screen information.
>
> If the chart application supports zooming, it should also support panning. Similarly, if the chart application supports panning, it should also support zooming. Panning should be designed such that the user always knows which way to move to bring more of the chart into view.
>
> If the zoom level can be configured by the user, there should be an easy way to return to default settings.

Equipment Issue(s)

> Zooming in helps the user to detail and zooming out helps the user to get context. However, the task of setting the zoom level can induce workload. The design of the zoom mechanism and controls can affect the how much workload is induced.
>
> One possible consequence of staying zoomed in is that the pilot could lose awareness of proximal, but off-screen threats. (In advanced, database driven EFBs that have knowledge of ownship position, some artificial intelligence could be built-in to alert the pilot to off-screen proximal threats.)

Problem Statement

Pilots can bring a paper chart close to the face in order to see fine details more clearly. In order to read the details on an electronic chart, bringing the EFB in close may or may not be an option. Also, electronic displays do not yet have a resolution that is even close to that of paper. As a result of both physical constraints and display technology then, many of the small elements on a paper chart will be difficult to read on an electronic chart.

One way to address this practical problem is by implementing zooming. Being able to zoom out, find the desired object, and zoom back in on that object is a basic function of electronic maps in general. Zooming in allows the user to see small details on the chart. By increasing the size of the details, their visual angle is increased even when the viewing distance to the EFB is unchanged. In addition, when the display is zoomed in, it is often less cluttered because there are fewer objects in the area of interest. Zooming out allows the user to see where he/she is in the context of the full chart, but at the expense of seeing all the detail.

While zooming is a useful feature, it needs to be designed both with performance and workload issues in mind. In terms of performance, zooming should be designed such that the user is able to orient him/herself within the complete display. A basic feature that should be supported is the use of visual edges to denote the end of the viewing area. Without visual edges, the user might try to zoom or pan when those actions are not applicable, which would be confusing. In terms of workload, designers should realize that there is additional workload associated with configuring the display to bring up desired information. The design of the zoom mechanism and controls can affect the how much workload is induced.

It is important to use zooming in concert with panning so that the user can always find a way back to display of the main chart area. This is especially important on small displays where it is more difficult to maintain one's orientation when zoomed in tightly.

Example(s)

Pre-defined zoom levels that the user can select from may generate less workload than variable zoom features, but they also limit the customizability of the display, which could reduce its usability. Magnifying-glass-style zooming is useful in that it allows the user to see detail while retaining context, and is fairly intuitive to use.

Evaluation Question(s)

- Does the zoom feature allow the pilot to select the specific region of interest easily?
- Can the user orient him/herself easily using zooming and panning together?

6.2.6 Procedures for Use of Electronic Charts in Part 121/135 Operations

Training/Procedures Recommendation(s)

> For multi-function EFBs, Part 121/135 operator’s policy should specifically define what other applications can or cannot be open and in use while charts are in active use (i.e., during taxi, takeoff, or on approach and landing).
>
> The operator’s policy should also address any special procedures that may apply to use of charts with integrated multi-function EFBs that have knowledge of the intended flight plan.
>
> The operator’s policy should also specify under what conditions charts that are not actively in use can be viewed for any EFB (not just multi-function EFBs).

Problem Statement

As stated in Section 2.3.1, Part 121/135 operators need to have a statement of their EFB operating policy. Because electronic charts are a high priority source of information during certain phases of flight, the policy statement must specifically address the priorities of the different EFB applications relative to charts. Even within the charting application, the operator's policy should specify under what conditions charts that are not actively in use can be viewed.

Example(s)

Flight crews may need to perform flight calculations during an approach. The operator’s policy should specify whether the approach plate can be out of view while using the flight performance application. An operator may choose to resolve this by stating that two EFB display units are required in the flight deck, and that one must always display the chart in use while the other EFB accesses any other applications.

Integrated EFBs may have knowledge of the intended flight plan. This would allow the next chart to be pre-selected for manual call-up at the appropriate time or the chart could be called up automatically. These procedures should be well defined.

Evaluation Questions

- Does the Part 121/135 operator's EFB policy specifically call out what other applications can be used when the electronic charts are actively in use?
- Does the operator’s policy address any special procedures that apply to the use of integrated multi-function EFBs?
- Does the operator’s policy specify under what conditions charts that are not actively in use can be viewed?

6.2.7 Orientation of Electronic Charts

Equipment Recommendation(s)

> If the chart display can appear in either track-up or north-up orientation, the visual format differences between the two must be salient so that pilots can easily and reliably recognize which orientation the display is in.
>
> Text and individual symbols (e.g., navaid or waypoint symbols) should not be rotated on track or heading-up charts because it is difficult to draw rotated text/symbols cleanly and it is difficult to read rotated text.

Installation Recommendation(s)

> If the EFB supports a track- or heading-up mode, it should be installed such that the track- or heading-up display is aligned properly within the flight deck. The aircraft longitudinal axis should be aligned with the vertical axis of the EFB to eliminate an extra mental rotation step.

Equipment and Training/Procedures Issue(s)

> Electronic charts may either replicate paper charts with north up, or give pilots the option of north up or track/heading up. North-up only runs the risk of causing errors because pilots must perform mental spatial transformations in order to follow the path. However, pilots are used to doing this. If a track- or heading-up option is provided, it may be easier to make tactical decisions and easier to compare the chart display with the navigation display view and with other displays of spatial information, specifically, TCAS, CDTI, weather radar, PFD, and EGPWS. (See 6.2.8 for related guidance.) However, it is not clear how the pilots will use track- or heading-up electronic charts and what types of errors they might promote, especially on aircraft with these other displays of spatial information.
>
> Since paper charts are accepted, and they do not support either track-or heading-up modes, these dynamic modes should be considered as enhancements over paper functionality. As such, there may be new training and procedural issues as well as software design issues if track- or heading-up modes are supported. For example, if users can choose between north-up and track-or heading-up, they may need some guidance as to when each of these modes is appropriate.

Equipment Issue(s)

> Creating electronic track- or heading-up charts is significantly more complex than creating electronic north-up charts because the designers must consider how to handle rotation of all the display elements separately.

Training/Procedures Issue(s)

> Pilots do not have much experience using north-up moving map displays. There may be need for a brief familiarization period with these displays.

Problem Statement

Paper charts are traditionally drawn in a north-up orientation. Pilots are used to using paper charts in a north-up orientation. Some pilots leave the chart oriented north-up and do a mental transformation to align the procedure on the chart with own aircraft heading/track. Some pilots (more likely general aviation pilots) will actually physically rotate the paper chart so that it is aligned with the longitudinal axis of own aircraft. Physical rotation of a paper chart is easy, but it may or may not be possible with electronic charts on EFBs.

In electronic charts, however, the display could be oriented north-up, track-up, or possibly even heading-up. Navigational moving maps are generally shown with track or heading up; north-up is usually reserved for a planning mode where the pilot is looking several miles ahead of his/her current location. Track- or heading-up displays are usually better for making tactical (near-term) decisions, such as which way to turn at the next waypoint along the intended route.

The decision to support a dynamic track- or heading-up display should be made having taken into account the additional complexity developing and using charts in these modes. If track- or heading-up modes are supported, then users must be able to distinguish between all the possible chart orientations, or else they will be confused and distracted. Displays that support these modes should also be installed such that they do not induce workload by requiring the pilot to make mental transformations between the display axis and the aircraft longitudinal axis. Text and individual symbols (e.g., navaid or waypoint symbols) should not be rotated on track or heading-up charts because it is difficult to draw rotated text/symbols cleanly and it is difficult to read rotated text.

Example(s)

If the EFB display can be in either north up or track up orientation, the pilot may confuse the two and end up following an incorrect path, which could lead to a violation of prohibited airspace, or even more severe consequences, such as controlled flight into terrain. (Even if a GPWS warning were sounded, the pilot may choose to discount it.)

It may be useful to allow a temporary track-up selection that reverts to north-up when the pilot releases the control.

Evaluation Questions

- If the EFB display supports more than one orientation, is the orientation in use evident from the display behavior, and/or mode annunciation?
- Could the pilot become confused about the display orientation and make errors? What types of errors could result from incorrect interpretations of the display orientation?

6.2.8 Using Charts with Other Flight Deck Displays of Spatial Information

Equipment and Training/Procedures Issue(s)

There may be cases where it is useful to compare electronic charts on an EFB with other flight deck displays of spatial information, such as TCAS/CDTI, weather (either from on-board radar, or datalinked from the ground), or terrain displays. The goal would be to ease the integration of all of the spatial information in these displays.

In order to make useful comparisons between all of these spatial displays, however, pilots must align the displays in terms of both orientation (north-up, track-up, or heading-up) and scale. Mismatches in either orientation and/or scale may increase the difficulty of integrating the information across displays.

It is possible that being able to physically bring the EFB display closer to the other spatial displays could reduce the mental effort required to compare information because the task would be more visual. However, if the scales are still mismatched the task could still be demanding.

If some information is duplicated on spatial displays in the cockpit (e.g., terrain is shown both on the EFB electronic chart, and on EGPWS), pilots could be confused by the fact that it is possible for the displays to provide different information if the underlying databases come from different sources.

If the EFB is connected to the FMS, it could run in a “slaved” mode where the EFB chart is matched with the FMS flight plan. However, this may or may not be desirable. It is possible that pilots would prefer to select the EFB chart manually in order to view other charts for reference purposes.

Problem Statement

Pilots frequently integrate information from multiple displays on the flight deck in order to make sense of a situation. They may want to look frequently between the EFB approach chart and the navigation, weather, terrain, and traffic displays, to compare and mentally consolidate the information contained on all of these displays. However, incompatibilities between these displays in terms of their orientation, scale, and even their underlying databases could make integration of information challenging.

Integrated displays of all these types of spatial information could be the eventual solution for this problem, but these are typically complex and expensive.

Example(s)

If pilots are used to being able to orient the paper chart to match a heading-up or track-up orientation, and if the chart display is not oriented the same way as the navigation display, they may spend more head down time trying to reconcile the two displays.

If the weather radar display is track up or the data linked weather display is north up and the EFB chart display is in the other orientation, it could lead to difficulty making comparisons between the two, as well as delays, and errors.

The pilot may use TCAS or a CDTI to identify and follow another aircraft into an approach procedure. This may require comparisons between the EFB chart and the TCAS or CDTI display.

Special attention should be paid to how the EFB supports late approach sidestep maneuvers. If the chart display is north up and the navigation display is track up, a pilot asked to change to a parallel runway late in the approach to a south facing runway in IMC may turn the wrong way to intercept the new runway. This error is more likely than some of the others relating to display orientation for two reasons: first, there would be no disconfirming information on the navigation display because that display would be showing only the first intended runway, not the requested new one, so the EFB chart would be the only source of guidance on turn direction; and second, the fact that this maneuver typically happens late in the approach and can therefore be a time-critical means that there will be little time to think about display orientation differences and recognize the potential for error before it occurs.

Evaluation Question(s)

- Can the pilot easily make comparisons between EFB charts and other displays, including the navigation, weather, terrain, and traffic displays, especially as it relates to awareness of potential threats along the approach path?

6.2.9 Access to Individual Charts

Equipment Recommendation(s)

The chart label of the currently selected chart should always be in view.

Users should be able to pre-select charts that will then be ear-marked by the software so that they can be brought up quickly (e.g., departure airport).

The chart application should promote good error management, meaning that it should help the crew ensure that the correct chart was selected and, if an error was made, it should allow common corrections to be made quickly.

The chart application should support multiple search methods (e.g., by name, by geographical region, by present position). Results of search should be ordered intuitively, both in terms of putting its best guesses at the preferred charts at the top of the list, and by putting the least likely to be used charts at the end of the list. Even if the most-used charts are not known, if the least-used charts are known, they should be at the end of the list. Integrated EFBs that have knowledge of the flight plan may be able to order search results more intuitively.

Since last minute runway changes are a high workload event, the electronic chart interface should make selection of alternate runways as easy as possible during the approach.

Training/Procedures Recommendation(s)

Flight crews may need training to learn how to access a desired chart because there are potentially many ways of accessing individual charts (e.g., custom searches for charts matching specific criteria), and some of these methods are new to electronic charts.

Equipment Suggestion(s)

If available, connectivity with the FMS can make it easier to access the right chart because the system would know useful information, such as the origin and destination airports, and the route of flight. The pilot would not have to make duplicate entries to get this information into the EFB.

If duplicate entries are required on the EFB and FMS, it would be useful to be able to position the EFB near the FMS CDU. This is especially helpful if the pilot is interrupted while making this entry on the EFB; then he/she could easily refer to both the FMS CDU and EFB to check and complete the entry.

If the crew has to divert while en route, selecting a diversion airport in the FMS could cause the EFB electronic charts to pre-select the approach charts associated with that airport for manual call-up.

If the distance to various airports is known, the electronic chart application could make it easier to access the "nearest" airport in case an emergency landing is necessary. Similarly, if the aircraft is far from it departure air field, the charts for that airport could be taken out of the pre-selected list.

Equipment and Training/Procedures Issues(s)

Potentially quicker access with electronic charts than paper charts, but poor implementations (with lots of steps) could increase overall workload. Ideally, charts should be available according to normal usage patterns for that operator, if those use patterns can be established in advance. Part 121/135 may have more well-established usage patterns than Part 91. The individual operator's preferences could even be implemented in the software. Ideally, charts should be available according to normal usage patterns for that operator, if those use patterns can be established in advance. Part 121/135 may have more well-established usage patterns than Part 91. The individual operator's preferences could even be implemented in the software. Accessing approach charts in a new way (using an electronic search function instead of paper) may make new kinds of errors possible. For example, it may be possible to search for a departure or arrival by some means other than through the particular airport that the departure or arrival is attached to. The potential for errors made possible by the available search and access methods should be examined.

Problem Statement

Putting charts into an electronic medium makes new capabilities possible. Among these is the ability to search for charts and access them in multiple ways, rather than just based on their relationship with a given airport. Access may be intelligently assisted by the system; for example, the system may give the pilot an ordered list of choices based on current position, destination, frequency of use, and likelihood of use based on the current flight plan.

Example(s)

If the EFB knows the final destination, it may provide a list of approaches for that destination, and if a diversion field is selected in the FMS, the EFB may automatically display the approach options for the new airport.

Connectivity to the FMS may be useful for return to field functions. If the aircraft experiences a failure that requires a return to the field after takeoff, and the pilot selects an approach chart for the field on the EFB or an arrival to the departure airport in the FMS, it would be nice for the other to bring up the corresponding arrival data automatically. This would reduce workload during a very high workload procedure.

Since last minute runway changes are a high workload event, it might be handy for the EFB interface to make selection of alternate runways as easy as possible during the approach. One way of doing this would be for the alternate approaches to an airport to be available on tabs or in a selection box so the pilot can see the options and select the desired one with one step, rather than having to reselect the airport to get a list of the alternate arrivals.

Evaluation Questions

- Are the means of accessing specific charts logical to the user?
- How can users identify errors in chart selection? Is it easy to make common corrections?
- Are there multiple ways of accessing charts?
- If there is FMS connectivity, does it improve accessibility to the charts in a logical manner? Does the system logic correctly anticipate user needs?

6.2.10 Knowledge and Display of Own-Aircraft Position

Equipment Requirement(s)

> Display of own-aircraft position must not be supported on non-georeferenced or not-to-scale charts (e.g., arrival and departure procedures).

Training/Procedures Recommendation(s)

> Pilots should be trained on the use, accuracy, and limitations of the display of own aircraft position.

Equipment Recommendation(s)

> Accuracy of the ownship display should be maintained across any display zoom levels.
>
> If there is a zoom feature, it should not allow the pilot to increase the scale beyond the point where the information is no longer accurate. For example, if the location of a ground track depiction on a chart is accurate within several hundred feet, it should not be possible to zoom in so close that accuracy within a few feet is implied.

Issues(s)

> Chart data are accurate up to a point, but they may or may not support display of highly accurate own aircraft positions. Both the accuracy of the information about the surface and the accuracy of the navigation information upon which ownship position is based can affect the overall accuracy of the displayed information.
>
> Display of own aircraft position on a chart can serve as a cross-check for the pilot's internal assessment of his/her position, but pilots could become over-reliant on the display, promoting a false sense of security. Therefore, the immediate display of any system failure in this capability becomes especially critical (see 2.4.9).
>
> If the electronic chart is connected to the FMS and has knowledge of own aircraft position, it could use this data to configure the chart automatically, even if own aircraft position is not displayed. However, it is not clear what would be the best way to use this information.
>
> Keeping the aircraft on the display is tricky with a north-up moving map display. (Honeywell has implemented this, and find this mode is useful.

Equipment Suggestion(s)

> In order to ensure that users do not infer a high level of precision in the display of ownship position, the symbol for ownship could be relatively large, such as a circle or an arrow-head shape. The size of the symbol could also be adjusted based on the estimate of navigation accuracy; less accurate information about ownship position could be depicted via an even larger ownship symbol.

Problem Statement

When own aircraft position is displayed accurately on a chart, it can be extremely useful to the pilot in cross-checking his/her internal estimate of ownship position. However, it is important that the pilot understand when own aircraft position may be in error, or unavailable so that he/she does not become overly reliant on this information.

Georeferenced charts are drawn to scale so accurately that an accurate reading of own-aircraft position can be correlated with a particular location on the chart. However, some charts, such as those for arrival and departure, are not usually drawn to scale. Own aircraft position cannot be displayed on charts that are not drawn to scale, or those that are not georeferenced because the information would be misleading, conveying the sense of greater accuracy than is really present.

Example(s)

If the EFB chart is zoomed, and the EFB is knows own aircraft position, the view could pan automatically so the aircraft stays in the center of the visible chart area, even if the aircraft position is not displayed. Or, if the chart stays fixed, should the view pan or shift when the aircraft passes the visible edge of the displayed area?

Training should emphasize that the primary flight display is to be used for navigation, not display of own-aircraft position on electronic charts. Pilots should also understand how own aircraft position will be displayed if it is off the scale of the current view.

If the update of own aircraft position is lost, the own aircraft symbol could be removed from the display, and an explanatory message could appear on the EFB.

Evaluation Questions

- When own aircraft position is displayed, is the displayed position accurate to within the scale of the chart? If the pilot zooms the chart display to show a close in view, does the display of own aircraft position remain accurate?
- Are pilots trained on the limitations of the display of own aircraft position?

6.2.11 Display Configuration and De-cluttering with Database Driven Charts

Equipment Recommendation(s)

If there is a de-clutter capability, it should not be possible for the pilot to remove safety critical information, such as terrain, obstructions, or special use airspace without knowing that it is suppressed. If such information can be de-cluttered, it should not be possible for the pilot to believe that it is not visible because it is not there.

Managing the display configuration should not induce significant levels of workload. That is, routine display configuration changes should be minimized.

Equipment Suggestion(s)

If there is a zoom feature, there should probably also be a coordinated de-clutter feature so that the display remains useful even when the user is zoomed out to see a large area of the chart. Otherwise, zooming out to view a large area may cause there to be too many objects on the display.

Equipment and Training/Procedures Issues(s)

Manual control over the display of individual information elements (e.g., obstructions, or navigational aids) could become quite complex. On the other hand, automatic display configuration could be frustrating for the user if it does not match the user's expectations.

Pilots may need training on how to configure and de-clutter the display. More training will be necessary for more complex user interfaces.

Furthermore, if safety-related information can be removed from the display, pilots may not recognize that they may exist even though they are not being depicted

Problem Statement

Some systems with typically dense displays give the use an option of de-cluttering the display by either selectively removing certain features or selecting one of several standard de-cluttering options. While this capability makes it easier for the pilot to see specific information more clearly, the suppression of certain safety-related data may lead to errors and oversights.

Potentially less clutter because may be easier to customize for specific audiences (e.g., only show data applicable to a particular operation) automatically.

User may have some control over clutter (e.g., select whether some types of data are shown or not). However, there is additional workload associated with configuring the display to bring up desired information.

Example(s)

One display option may show only navigation aids and the approach path, with terrain and obstruction data removed. There should be a clear indication that safety-related data are missing from the display. Ideally, the whole format of the display should appear distinctly different from the usual format, rather than the indication being limited to a small message or symbol in a corner of the display.

Many new navigation display formats allow pilots to selectively display “layers” containing different types of objects: navaids, terrain, airways, etc. It is possible that some electronic chart implementation will allow the same type of control over what is displayed and what is not displayed.

Evaluation Questions

- Are the pilot’s choices regarding display configuration supportive of the pilot’s tasks and situation awareness?

- If the pilot can selectively remove certain safety-related display features, such as terrain or obstructions, does the display indicated that these data have been removed so the pilot doesn't assume that there are no potential threats to the aircraft because they aren't being shown?
- Do the means of configuring the display require taking attention away from other tasks for extended periods?
- When safety related information is suppressed, is this clear to the pilot in a way that he or she cannot overlook it?
- Are the various de-cluttering options logical and supportive of specific pilot tasks, such as understanding the approach trajectory, and understanding potential threats and constraints?

6.2.12 Color Coding of Chart Symbols

Equipment Issues(s)

> Symbols themselves may eventually be colored, particularly on database driven charts. However, but no standards have been developed to date on what colors should be used, or how symbols should be grouped in terms of color.
>
> If symbols are color coded, and other background elements are also color coded, such as terrain, a layering system will need to be developed to ensure that every element appears in its correct color.

Problem Statement

VFR charts rely on color more than IFR charts today. Even IFR charts are using color to depict terrain now. See related guidance on color in 2.4.3.

Example(s)

Brown is preferred for terrain (over green) because green has the connotation of "okay". Brown is consistent with some paper charts, and also with the attitude display. However, green is used to depict safe terrain in EGPWS.

Airports may be color coded based on weather conditions or utility for the current flight.

Evaluation Questions

- Are symbols color coded? What is the underlying rationale for choosing symbol colors?

Appendix A: Related Literature

Section 1: FAA Documents on the EFB

Federal Aviation Administration. Advisory Circular AC 120-76. (July 2002). *Guidelines for the certification, airworthiness, and operational approval of electronic flight bag computing devices*.

(DRAFT October 1999) AC-20-FIS: Safety and Interoperability Requirements for Flight Information Services (FIS) Equipment. Update?

FAA Memorandum (14 May 1998) (by Mike DeWalt): Approval of Avidyne Navigation Display and DO-178B.

AC 25-11 (16 July 1987) Transport Category Airplane Electronic Display Systems.

AC 91.21-1 (20 August 1993) Use of Portable Electronic Devices Aboard Aircraft

FAA Document 98-AIR-DATIS: Safety and Interoperability Requirements for Digital-Automatic Terminal Information Service (Digital-ATIS).

AC 23-1311, (as amended), Installation of Electronic Displays in Part 23 Airplanes,

FAA Policy Statement ANM-99-2, Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks.

FAA Policy Statement ANM-01-03, Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods for Compliance for Flight Deck Certification,

DOT-VNTSC-FAA-00-22, Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags (EFBs), Version 1: Basic Functions. This reference is recommended as general guidance to ensure that human factors/pilot interface issues are resolved.

Section 2:

General

MILSTD1472F (23 August 1999) Department of Defense Design Criteria Standard Human Engineering.

Society of Automotive Engineers (SAE) Aerospace Behavioral Engineering Technology (G-10) Subcommittee (August 2000) *DRAFT Aerospace Recommended Practice (ARP) on Human Factors Criteria for the Design of Multifunction Display for Civil Aircraft* (ARP 5364).

Federal Aviation Administration Technical Center (January 1996). *Human Factors Design Guide for Acquisition of Commercial-off-the-shelf Subsystems, Non-Developmental Items, and Developmental Systems—Final Report and Guide (Sections 7 and 8). http://www.tc.faa.gov/act-500/hfl/products_index.htm*

Society of Automotive Engineers (SAE) Aerospace Behavioral Engineering Technology (G-10) Subcommittee. (1996) Aerospace Recommended Practice (ARP) on *Human Engineering Recommendations for Data Link Systems* (ARP 4791).

FAA Advisory Circular 120-53. (5/13/91) *Crew Qualification and Pilot Type Rating Requirements for Transport Category Aircraft Operated Under FAR Part 121* (AFS -200).

Crane, J.M., Bang, E.S, and Hartel, M.C. (1994). *Standardizing interactive display functions on the 777 flight deck.* In Proceedings of Aerotech 1994. (Paper No. 942093) Society of Automotive Engineers; Warrendale, PA.

Society of Automotive Engineers (SAE) Aerospace Behavioral Engineering Technology (G-10) Subcommittee. (1991) Aerospace Recommended Practice (ARP) on *Electronic Display Symbology for EADI/PFD* (ARP 4102/7).

System Messages, Errors and Alerts

FAA Advisory Circular (16 August 1999) *Guidelines for Design Approval of Aircraft Data Communications Systems* (AC 20-140).

Federal Aviation Regulations (FAR 23.1322, FAR 25.1322, FAR 27.1322, FAR 29.1322)

Terrain Awareness and Warning System (TAWS) Technical Standard Order TSO C151a http://av-info.faa.gov/tso/

SAE ARP 4102/4 Flight Deck Alerting Systems.

Graphical User Interface Style Guides

Microsoft Corporation. *The Windows™ Interface Guidelines for Software Design.* (1995). Redmond, Washington: Microsoft Press.

Apple Computer, Inc. *Macintosh™ Human Interface Guidelines.* (1992). Reading, Massachusetts: Addison-Wesley Publishing Company.

Open Software Foundation (1993). OSF/MOTIF™ Style Guide (Revision 1.2), Englewood Cliffs, NJ: Prentice Hall.

Section 3: Electronic Documents

NASA/FAA Operating Documents Project Final Report.

Dillon, A. (1994) *Designing Usable Electronic Text*. Taylor & Francis: Bristol, PA.

Rosenfeld, L. & Morville, P. (1998) *Information Architecture for the World Wide Web.* O'Reilly & Associates: Sebastopol, CA.

McKinley, T. (1997) *From Paper to Web.* Adobe Press, Macmillan Computer Publishing: Indianapolis, IN, USA

Section 4: Electronic Checklists

Degani, A. & Weiner, E.L. (1990). *Human Factors of Flight-Deck Checklists: The Normal Checklist.* (NASA Contractor Report 177549). National Aeronautics and Space Administration Ames Research Center: Moffett Field, California.

Degani, A. (1992). *On the typography of flight-deck documentation.* (NASA Contractor Report 177605). Moffett Field, CA: NASA Ames Research Center.

Federal Aviation Administration. (4/24/96) *Operational Use and Modification of Electronic Checklists.* (AC-120-64).

Add CAA report references...

Section 6: Electronic Charts

Wright, M. W. and Barlow, T. (March 1995) *Resource Document for the Design of Electronic Instrument Approach Procedure Displays.* DOT/FAA/RD-95/2.

SAE G-10 Draft Aerospace Recommended Practice on Electronic Charts

SAE G-10 Draft ARP on SMM?

RTCA/DO-257, Minimum Operational Performance Standards for the Depiction of Navigation Information on Electronic Maps.

Appendix B: Acronyms

AMJ	Advisory Material Joint
AQP	Advanced Qualification Program
ECAM	Electronic Centralised Aircraft Monitor
ECL	Electronic Checklist
EICAS	Engine Indication and Crew Alerting System
EFB	Electronic Flight Bag
FAA	Federal Aviation Administration
FMC/FMS	Flight Management Computer/Flight Management System
GUI	Graphical User Interface
JAA	Joint Aviation Authorities
LOE	Line Oriented Evaluation
MEL	Minimum Equipment List
PDF	Portable Document Format, a page-definition language
POH	Pilot Operating Handbook
PAI	Principal Avionics Inspector
POI	Principal Operations Inspector
QRH	Quick Reference Handbook